OUR HARBORS AND INLAND WATERWAYS

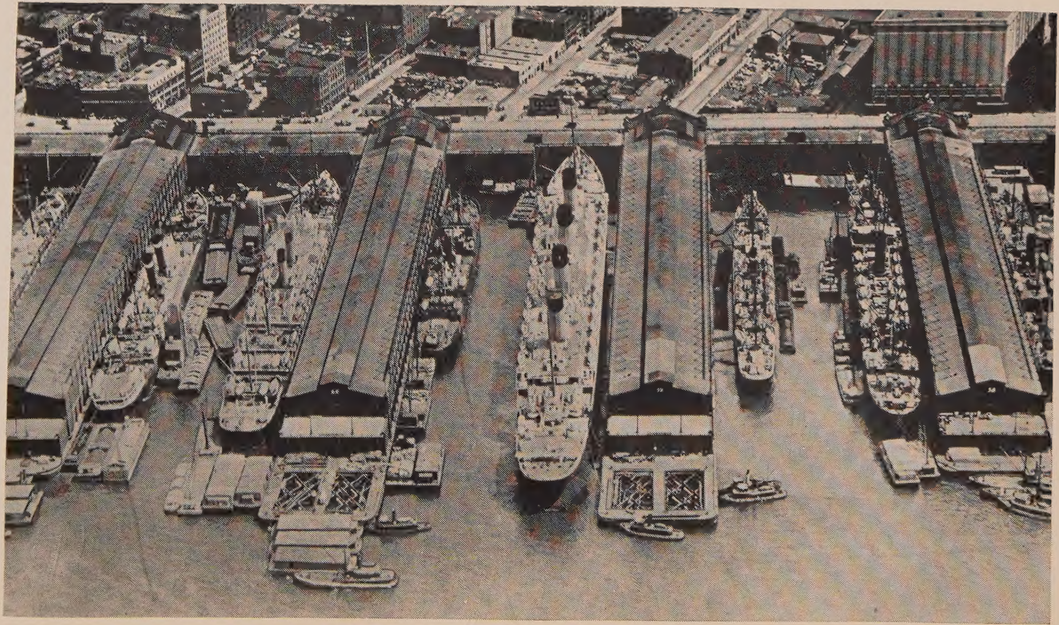
FRANCIS A. COLLINS

1^{50}

75¢

~~75~~
c

WITHDRAWN
UTSA LIBRARIES



LOOKING DOWN ON A BUSY SECTION OF NEW YORK HARBOR (NOTE THE EIGHT OCEAN LINERS INCLUDING THE S.S. "OLYMPIC")

OUR HARBORS AND INLAND WATERWAYS

BY

FRANCIS A. COLLINS

AUTHOR OF "MOUNTAIN CLIMBING," "SENTINELS ALONG
OUR COAST," "THE AIR MAN," "THE WIRELESS
MAN," ETC., ETC.

*ILLUSTRATED WITH
PHOTOGRAPHS*

THE CENTURY CO.
New York & London

Copyright, 1924, by
THE CENTURY CO.

PRINTED IN U. S. A.

LIBRARY
University of Texas
At San Antonio

The author is especially indebted to Major Elihu Church, Transportation Engineer of the Port of New York Authority, for the privilege of consulting the immense volume of information he has collected on commercial engineering both at home and abroad, as well as to his kindness in interpreting this material.

CONTENTS

I Bidding for World Trade 3
II The Earliest Harbors 22
III Outwitting the Sea 37
IV American Harbor Problems . . . 65
V Gateways of the Atlantic . . . 90
VI The Port of New York 106
VII Looking Down on New York Harbor 123
VIII Rise of the Pacific Ports . . . 147
IX The Harbors of the Great Lakes . 167
X Modern Gulf Terminals 181
XI Evolution of the Canal 199
XII The Science of Canal Building . . 219
XIII Proposed American Waterways . . 235
XIV Boston to the Gulf Canal . . . 259
XV Some Economic Aspects 276

LIST OF ILLUSTRATIONS

Looking down on a Busy Section of New York Harbor (Note the Eight Ocean Liners Including the S.S. *Olympic*.) . . . *Frontispiece*

FACING PAGE

A Trackless Railroad for Handling Freight . 80

Dock Loading Machinery on the Great Lakes . 80

An Auto Dock Crane in Operation 81

A Tiering Machine in Action 81

Loading Coal at the Rate of a Car a Minute . 96

A Typical New York Dock Scene 97

A Typical Scene in New York Harbor . . 112

Loading Railroad Trains Afloat 113

Modern Dock Equipment for Transhipping Cargoes 113

A New York Dock Street with Its Overflow of Freight 128

Air View Showing Intensive Development of New York Docks 129

An Aerial View of San Francisco Before Its Recent Intensive Development 160

An Ore Dock on the Great Lakes 161

LIST OF ILLUSTRATIONS

Lake Steamers Waiting to Enter the "Soo" Canal 161

The After Deck 208

Dock Equipment for Loading Ore and Coal . 208

The Entrance to the "Soo" Canal 209

The Largest Canal-Boat Terminal in the World (New York Harbor) 272

An Ancient Substitute for the Canal Lock . . 273

Locks on the New York Barge Canal . . . 273

OUR HARBORS AND INLAND WATERWAYS

OUR HARBORS AND INLAND WATERWAYS

CHAPTER I

BIDDING FOR WORLD TRADE

THE United States stands to-day on the threshold of a great commercial adventure. Since the World War fleets under every flag have been diverted from long established trade routes to new destinations. A score of American ports on either seaboard, the Gulf and the Great Lakes are bidding for this world trade. Rivalry among these widely scattered cities has never before been so spirited. The immediate future may witness the rise of comparatively unimportant ports, far from the conventional trade routes, to dominant positions, and the possible decline of cities at present of the first class.

The prizes for which our ports are bidding are fabulous. The foreign trade of the United States is in round numbers $8,000,000,000 a year. A trifle more than half of this passes in and out of New York harbor. The other ports on the Atlantic share roughly almost $3,000,000,000, while a billion goes to the ports of the Gulf of Mexico and another billion to the harbors of the Pacific coast. The old standards of comparison for measuring fabulous treasure, a king's ransom, the freight of golden argosies or the wealth of the Indies, seem trifling by comparison.

Glance for a moment at the rival ambitions of our principal seaports and it will be seen that the battle is on in earnest. All the Atlantic and Gulf ports from Montreal to Galveston are competing with one another for the rich prize of European trade. Those lying farthest north have the advantage of being nearer Europe. The most favorable geographical position is held by Montreal.

The construction of a ship canal by way of Montreal to the Great Lakes, it is believed, will divert an enormous volume of shipping which now passes to and from Europe by way of New York. The great wealth of the Northwest may find a new outlet by this route, and Montreal may encroach upon New York.

Further south Boston with many natural advantages is making a spirited bid for world trade. Here the harbor lies close to the sea and is always open to navigation. Boston is in touch with a great industrial area and is in direct communication by rail with the West. The natural advantages of her harbor are being intelligently developed, and the port equipped with efficient machinery. In transhipping freight, Boston was once a great world port, sending ships to the furthermost seas and she may regain this position.

Although New York at present holds a preëminent position as a world port, her future is by no means assured. Lying near the sea, she enjoys one of the greatest natural harbors in the world. A dozen railroad lines connect her with the South and West. She has profited by the enormous waterborne traffic from the central and northwest sections for a century. New York, nevertheless, is begining to feel the strength of rival ports. She has largely lost her grain trade to Montreal, and the trade from the West may be still further diverted into new channels. New York is severely criticized for failing to keep up with the times in providing efficient harbor equipment, and the problem is being studied by local engineers with anxious attention.

Several other Atlantic seaports have entered the race, notably Philadelphia, Baltimore, Norfolk and Charleston. In each case, these cities have felt the stimulus of the World War upon their trade, and are thoroughly awake to the possibilities of the future. They have engaged the services of experts to design improvements for their harbors, and are expending vast sums in deepening channels, building docks and warehouses and equipping them with modern machinery for handling cargoes. Philadelphia, although far from the coast, has open navigation throughout the year. She stands at the center of a great manufacturing area, and has even more direct rail connections with the West than has New York. Baltimore and Norfolk enjoy wonderful harbor facilities and Charleston has probably the best natural harbor on the Atlantic seaboard after New York.

The possibilities of growth of the Gulf ports are limitless. It will be a surprise to many to learn that New Orleans occupies second place among American ports and Port Arthur, Tex., third. Mobile and Galveston are growing at a surprising rate. New Orleans takes toll of the enormous commerce which passes her door from the Mississippi valley. The great wealth of the Northwest finds an outlet through other ports to the west on the Gulf. An immense volume of shipping passes directly from the Gulf ports to and from Europe. The Panama canal opens the way to the far East, and the Gulf ports are conveniently placed for sharing in the trade both to the east and west coasts of

South America. The Great Lakes may be connected by canal with the Mississippi, thus diverting their trade to the Gulf of Mexico. New Orleans looks forward with confidence to becoming the greatest port of America, if not of the world.

On the Pacific coast several great harbors are competing for the rich prizes of Eastern commerce. The reward of success here is also amazing. The wealth of the vast region west of the Rockies flows through these harbors and the countries on seven seas are within striking distance. San Francisco, with probably the finest natural harbor in the world, occupies a valuable strategic position. Her plans for developing her harbor are probably without parallel. The broad bay, seven miles in width, may be crossed by tunnel or bridges, or both, and the limitless waterfront developed along modern lines.

Los Angeles has built a remarkable artificial harbor capable of accommodating the commerce of a great world port. Lying as she does at the focus of many lines of railroad and convenient to the Panama Canal, the city has an excellent position in bidding for trade with Europe, both coasts of South America and the Orient. Los Angeles is already the first city of California in point of population. Owing her growth to causes other than commerce, the city found herself twenty miles from the sea. She lost no time in going about the difficult task of creating a great artificial harbor which is already one of the largest of its kind in the world.

Under the stimulus of the World War the harbor of Seattle, for instance, in 1918 became for a time the second port in the United States. She enjoys one of the most remarkable natural harbors in the world. With comparatively little labor an extended waterfront facing Puget Sound has been transformed into a great harbor, while back of the city lies Lake Washington which offers unlimited opportunity for developing a great inland port. The machinery for the rapid transhipment of cargoes installed at Seattle is equal to that of any port in the world. Tacoma to the south is well placed in bidding for the trade of the Pacific. Portland on the Columbia River is accessible from the sea.

The World War supplied a complete and exhaustive test of our harbor facilities. The struggle had not been anticipated. A number of seaports were suddenly called upon to handle an immensely increased tonnage. The situation may be compared to the tests of steel girders when they are subjected to degrees of pressure and to strains of various kinds, far more severe than they are commonly called upon to endure. Our harbors had been developed, as a rule in a hit or miss manner, to meet the demands of the hour. Little effort had been made to anticipate future increase or to evolve a comprehensive, unified plan of development.

Under these exhaustive war tests many harbors broke down. Incoming ships could find no docking facilities. The strain of handling the increased tonnage paralyzed the facilities for working cargoes. In several ports immense quantities of supplies overflowed the warehouses and shelters and were piled upon the wharves awaiting shipment.

A wealth of food-stuffs, material of war and ammunition, which were imperatively needed elsewhere, were forced to wait for long periods.

An interesting object lesson in harbor engineering was first of all afforded us. As the demands upon a harbor increased, the weak points in its design soon became obvious. The movement from railroad cars or inland craft to the docks of outgoing vessels was slowed down. As a result priceless time was lost by holding ships in port. The time required to make the trip to Europe and return remained much the same, but the ships were often held for weeks awaiting the cargoes which were ready in other parts of the harbors.

A ship capable, under normal conditions, of making the round trip between America and Europe in six weeks, including time for loading and unloading at each end of the voyage, was often slowed down to an itinerary of a round trip every twelve weeks. Obviously the efficiency of the vessels was thus cut in half. No matter how badly the cargoes might be needed at the front, the movement of freight was absolutely dependent upon the facilities of harbors thousands of miles away. The size of the docks, the number and form of derricks available for loading and unloading, a hundred details which go to make an efficient, scientific harbor, became influences of the greatest importance in actually deciding the war.

Had New York harbor been unable to meet this extraordinary situation, the war might have been lost. Enormous supplies of ammunition, food, clothing, all the sinews of war, were poured into New York from all parts of the country in unprecedented volume. Great fleets of ships passed in and out of her harbor at the rate of 2,000,000,000 tons a year. The great docks were soon crowded to capacity and beyond, and the broad waters of the harbor served as anchorages for hundreds of craft. Its facilities for handling freight were taxed to the utmost. Much of her machinery was slowed down and almost paralyzed by the vastly increased volume of work required of it.

Nevertheless the great natural advantages of the harbor, though its equipment was incomplete, proved sufficient to meet the demands made upon it. The eyes of the world were turned anxiously upon New York, which continued throughout the war to be a vital strategic point. The necessity of harbor equipment and general efficiency in the operation of a great harbor was perhaps never so strikingly illustrated. New York harbor may be said to have won the war.

The World War shifted almost over night many trade routes which had been undisturbed for centuries. The effect upon many of the harbors of the United States was amazing. The comparatively unimportant port of Seattle, so remote from the scene of war, became the second port in the United States in amount of tonnage entering its harbor. Every port on the Atlantic and Pacific seaboards, the Gulf of Mexico and the Great Lakes felt the stimulus to some extent.

The lesson of the war has not been lost. With its close a new era has been opened in the history of world shipping. The commerce of the world to-day meeting at new focal points, both in America and Europe, brings new opportunities. The great markets of the world are looking for new customers and the distribution of the great food supply from its sources is being diverted to new channels.

America is thoroughly awake to the possibilities of the new world trade. In the past few years many American cities have made elaborate plans for harbor development. In many instances commissions, headed by specialists in this branch of engineering, have visited the great harbors of Europe and America and made studies of their port problems and achievements to be borrowed or adapted for local application. It is recognized that the development of our coastal cities will be in the future more than ever dependent upon their success in solving harbor problems. Many cities of the United States, it will be seen, may grow in wealth and population or remain stationary or retrogress in the next few years in proportion as their harbors are intelligently developed.

One half the United States knows little or nothing of the commercial life of the rest of the country. The grouping of American ports in the order of their importance comes to the average man as a surprise. New York is known of course to hold a preëminent position among world ports, but it is not generally realized that some fifty-two per cent. of the total foreign commerce of the United States passes in and out of her harbor. The average man would doubtless make a very poor guess as to which ports fill the first five or ten places in the order of the volume of their shipping.

More than eighty per cent. of the total waterborne tonnage of the United States passes to-day through sixteen ports scattered along the Atlantic and Pacific seaboards, the Gulf of Mexico and the Great Lakes. Of this tonnage fifty-two per cent. is carried under the American flag. The sixteen leading ports in the order of their importance are as follows: New York, New Orleans, Port Arthur, Philadelphia, Galveston, Baltimore, Buffalo, Boston, Norfolk, Baton Rouge, San Francisco, Portland, Ore., Chicago, Los Angeles, Newport News, Seattle.

In planning the seaports in the past it seemed only necessary to provide adequate docking facilities. To-day the problem is far more complicated. All parts of a harbor must be brought closely in touch with one another. As harbors increase in size there is inevitably an immense amount of lost motion in transferring freight on its arrival from the interior, to the docks or points of departure. The movement of cargoes from one dock to another, or to the industrial centers, or the reverse operation, must be facilitated in every way. So keen is the rivalry of modern harbors that the loss of every hour in this movement must be considered.

A port with great natural advantages may fail of its purpose if it does not keep up with the advance in the science of harbor building. The great hinterland whose products drain to the seaports, and in turn draws its supplies from such centers, is directly affected by the efficiency of the harbors. Every consumer within a radius of hundreds of miles, perhaps the entire country, profits or suffers by harbor conditions. The cost of material for the clothes one wears, or the food consumed, may depend on the movement of freight to the nearest port of entry. Should these products not be attracted to the nearest port they may seek entrance elsewhere and costs of transportation will be added to the price. The movement of freight in New York harbor, for example, affects the prices of many luxuries and necessities of life consumed in interior cities, thousands of miles distant.

The superior efficiency in cargo handling of many of the ports of Europe compared with those of America is at first almost unbelievable. The ports of Liverpool, London, Hamburg or Rotterdam, for example, although but one fifth the size of New York harbor, can handle the same volume of traffic. Several European ports, notably Marseilles, average 1,500 tons of cargo transhipped over every foot of equipped quay, as compared with only 150 tons per foot in New York harbor. This amazing contrast is partially explained by the fact that these foreign harbors are of the "dug out of the mud" class, in other words they have been designed and built for efficiency, while America's great harbors are natural harbors, and their efficiency is affected by their natural faults as well as by the advantages of their great size. The increased efficiency of the European harbors is largely due to their superior scientific equipment.

Again a great world port may be crowded with commerce and seething with activity and yet fail to bring wealth to the city surrounding it. There are several such ports whose names are household words the world over which receive little direct benefit from such activity. If the harbor is merely the scene of transhipment from one vessel to another, or to the railroads, the volume of commerce, however great, will not serve to build up a prosperous community. Practically the only sources of income will be from the rental of docks and the wages paid to the dock-hands. The port of Rotterdam, for instance, gains comparatively little from the shipping continuously gathered there. An immense volume of commerce reaches this port from inland waters and is transferred to ships carrying the flags of every maritime nation in the world. More freight is transhipped at Rotterdam, at this writing, than at any other port on the continent of Europe, but the city reaps very little benefit from it. A parallel might be cited in the case of several busy American ports.

In order to profit from its shipping, a port must, therefore, supplement its commerce with great industrial activities. The busy docks must help to supply great factories, and these industries in turn will transform imported crude materials into finished products to be carried away in other ships to widely scattered ports.

For instance, a port may receive shiploads of hides and leathers and, having no facilities for manufacture, merely tranship these cargoes to other vessels or to railroad cars to be carried elsewhere. The labor required to handle hides is not skilled and the port has only profited by their wages and the docks charges. Let the shiploads of hides come to a great industrial port, and the cargo will supply tanneries and factories employing thousands of operatives. By the time the finished product of shoes is ready for shipment, employment has been provided for a great variety of workers. These in turn make it necessary for stores, banks, schools and theaters to be built and thus a prosperous city is built up.

The development of a port is a far more complicated problem than at first appears. The modern engineer must study the principles of port development from many angles. It is no longer enough, it will be seen, for a city possessing a good natural harbor to sit back, as it were, and wait for commerce and prosperity to come to it. The possibilities of its harbor must be thoroughly understood in every detail. Modern equipment, especially suited to the problem at hand, must be installed and the cost of transhipment must be reduced to a minimum. Every industrial opportunity must be seized upon and developed. The attractions of rival ports must be closely watched.

The latest ideas in port development in Liverpool, London, Hamburg, Rotterdam and elsewhere are being adapted to suit the individual needs of ports widely scattered along the Atlantic and Pacific coasts, the Gulf and the Great Lakes. Profiting by the experience of the war, many of the great harbors of America are for the first time in their history being intelligently developed.

CHAPTER II

THE EARLIEST HARBORS

SINCE the days when the earliest navigators ventured out upon the sea, harbors of some form have been essential to their voyages. For many centuries the primitive craft which carried abroad food, merchandise or the fighting men of the race depended upon undeveloped natural harbors for protection. As sea-going craft grew larger and commerce increased, the navigators matched their wits against the sea by improving natural harbors and building artificial havens. By the time the ancient trade routes had become clearly defined the science of harbor building had reached a surprising development.

A modern pilot would have felt very much at home could be have entered the ancient ports of Tyre or Sidon. On approaching either port from the sea, by day or night, he would have been able to pick up the entrance by their lighthouses. In both cities the anchorages were protected against the sea by great moles built of stones. In the spacious anchorages were many well-constructed quays and warehouses. To such a development had harbor building been brought some 3,000 years before the Christian era.

The city of Tyre was built upon a peninsula, flanked on either side by spacious artificial harbors. These had been built with skill at an enormous expense by constructing moles formed of loose rubble. The port problem at Sidon was similar and had been solved in much the same manner. The merchant ships were brought alongside well-defined quays for loading or discharging their cargoes, an amazingly efficient method for the period. Doubtless the improved harbors contributed largely to the growth of these cities and their extended commerce. So substantially were these ancient harbors constructed that their boundaries may still be traced, fifty centuries later.

At Alexandria the science of harbor building was carried much further. Nature had done much toward forming a great natural harbor. Just before the city lies the low island of Pharos, affording natural protection against the sea. From opposite sides of the harbor, two capes jut out, almost completely enclosing a large area of water and forming a fine natural harbor. The skill of the ancient engineers who utilized these advantages challenges the admiration of modern harbor builders. The two projecting capes were extended by means of breakwaters, forming a harbor capable of holding great fleets of ships.

Upon the island of Pharos was erected the famous lighthouse which has made the name a household word. This tower, erected about 270 B. C., was one of the seven wonders of the ancient world and stood for some fifteen centuries. Its height is reported by some historians to have been 416 feet and by others more than twice that. The primitive bonfire which was burned atop this tower was visible by reflection for upwards of a hundred miles at sea. No other harbor, ancient or modern, has been marked by so imposing a monument.

The great port of Alexandria, with its fleets of ships, was made possible by the cheapness of waterborne traffic of the river Nile and the development of inland waterways. The Nile drained a great, rich valley. Its waters regularly overflowed its banks, fertilizing an immense area. The native engineers of the period have left evidence of their skill in "disciplining" the river by controlling its course and maintaining permanent channels and harbors. The great agricultural and mineral wealth of the valley was floated cheaply from point to point and finally to the sea.

The cheap transportation made possible by the traffic of the Nile helped build up great cities whose ruins, thousands of years after, are still the marvel of the world. The commercial fleets which once traversed the Nile had a surprising development. Models of these ancient craft discovered in Egyptian tombs show that the passenger boats were furnished with beds allowing space beneath for "steamer trunks." The private yachts of the period carried orchestras among other luxuries.

The engineers of ancient Greece devoted great attention to harbor building, and their work in developing the harbors of Rhodes, Salamis, Corinth, Syracuse and Athens has been studied with great interest by modern engineers. The fanciful scheme of erecting a colossal bronze figure astride the harbor entrance at Rhodes at least indicates that they were masters of sea-wall building. Their masterpiece, however, was the harbor at Piræus, the port of Athens. Taking advantage of the natural harbor at this point, three great basins were built capable of accommodating 400 ships, the work being completed in 490 B. C. Piræus lies three miles from Athens, and the road to the capital was protected against land attack by formidable stone walls on either side for the entire distance.

The great artificial harbor of Carthage played an important part in history, and its strength served in an unexpected manner to change the course of ancient civilization. At an enormous outlay of money and labor a great harbor had been built, consisting of two basins enclosed by heavy breakwaters. These were connected by a channel seventy feet in width. In the inner basin was accommodation for 200 ships. The main arsenals and store-houses faced the inner basin. When Scipio besieged Carthage with his Roman fleet, he closed the harbor by building a dam across the single entrance, thus bottling up the home fleet. The Carthaginians set to work to cut a new entrance in the artificial breakwater, but so stoutly was it built that the city fell before an outlet could be made for their fighting ships and Carthage was destroyed.

The Romans displayed a natural genius for harbor building, and many of their harbors, built of enduring stone, still stand throughout Europe. The ancient harbors, as a rule, were designed to accommodate small craft of light draught, but the Romans built for the future. The harbor of Civita

Vecchia, built 2,000 years ago, is still serviceable for vessels with a draught of twenty feet. Profiting by the examples of the Phœnician and Greek engineers, the Romans showed amazing ingenuity in utilizing natural harbors as well as constructing artificial ports in exposed positions.

One of the curiosities of this construction are the harbor walls at Ostia, once at the mouth of the river Tiber. During more than twenty centuries the sea had retreated, until the old walls are now left high and dry, twenty miles inland. The Romans sought to safeguard their commerce by building harbors throughout the Mediterranean, and later on the Atlantic coast of Western Europe, including the British Isles. They built better than they knew and twenty centuries later much of the commerce of the world, carried in craft propelled by mysterious new forces, still finds protection behind these ancient sea-walls.

The fleets which ventured forth from these harbors or sought shelter in them would appear very crude to modern eyes. Many of them were composed of open boats without protective decks of any kind. The freight was left exposed to the waves which broke over the low craft. The science of navigation was little developed at that time, and the loss in sea shipment was extremely high. Even the largest boats of these ancient maritime nations were very small and crude. With such craft, nevertheless, the Phœnicians, the Greeks, Romans, Carthaginians and other maritime nations built up a great world commerce. The voyages between the great seaports of the period were often made on a fairly regular time schedule.

The rapid rise of England to the position of the dominant maritime power of the world was largely due to her fortunate geographical position. "Environed on every side by the sea," the long coast made it possible for fleets to reach many ports from which the products of the interior could be brought at slight expense. Her coast abounded in excellent natural harbors, which for centuries required comparatively little development. As her sailing craft increased in size channels were deepened and artificial harbors constructed to accommodate them.

Could one foretell the growth of the trade routes of the world, it would be a simple matter to prophesy the future of cities and nations. The next century may hold many surprises in the rise and fall of nations, as has the past, to be largely determined by the shifting of world trade routes. Great empires rose and flourished, enriched by commerce, and with its passing have declined and been forgotten.

The greatest city of the ancients, Babylon, grew up at the chance junction of caravan routes with the river Euphrates. The commerce borne overland between the East and the West was here intercepted by routes, both land and water, tapping many rich regions. Another source of wealth was the wonderful system of canals which helped to develop the great inland port of the ancient world.

Egypt, at a later period, owed her wealth and civilization largely to the cheap transportation made possible by the Nile traversing a great and fertile valley. The Nile was in turn supplemented by many canals which are believed to have been constructed some 10,000 years ago. At the mouth of the Nile the great natural harbor, developed with surprising engineering skill, was a development of commerce interestingly similar to that of the Mississippi River, with its Gulf Ports, many centuries later.

The rise of Phœnicia, Greece, Rome and Carthage on the Mediterranean Sea to world power can be traced directly to their fortunate position on trade routes and the ability to seize the commercial opportunities thus offered. Their fleets in turn entered every harbor of the known world, carrying the products of the East throughout the Mediterranean and returning with the products of other lands. No later commercial age has shown greater enterprise and daring in extending trade routes to distant lands. The open galleys of the Romans, for instance, traversed the length of the Mediterranean, ventured out upon the Atlantic and crept up the western coast of Europe to England to bring back cargoes of tin.

In the Middle Ages the great trade routes again shifted and the main artery of commerce lay through the Mediterranean and up the Adriatic Sea. At a convenient point the commercial fleets unloaded their cargoes which were then carried overland, taking advantage of natural waterways, to the North Atlantic. At the point where this transhipment took place, there rose the beautiful city of Venice. Like many other cities, ancient and modern, which lay on great trade routes, it took its toll of commerce and Venice grew rapidly in population and wealth.

The fall of Venice from a great port came unexpectedly, a freak of chance not uncommon in the history of world commerce. During her prosperity the great trade route from the East ran overland to the Mediterranean, where freight was carried by boat to Venice, to be again unloaded and carried overland to western Europe. When vessels began to make the entire voyage around the Cape of Good Hope, up the African and

European coasts, freight rates took a sudden drop. The overland route by way of Venice could not compete with the new all-water route, and Venice was doomed.

Another unexpected shifting of trade routes made Spain for a time the dominant country of Europe and the world. Her rise was due to the discovery of America and the creation of new trade routes across the Atlantic. The enormous wealth in gold and silver brought by the treasure ships from the New World, and the commercial trade which followed, was brought for a time mainly to Spanish ports. Under the stimulus of the new trade routes, Spain grew rapidly, and as a result, her influence was felt throughout Europe. Her armadas dominated the coast of Europe. Like Venice she entered upon her greatest era.

Next in turn Holland rose to wealth and power largely because of her fortunate geographical position on the western coast of Europe. Her fleets carried a great commerce for the period back and forth across the Atlantic. This oversea trade was supplemented by a remarkable system of canals traversing the country. It was thus possible to bring food and other products from all parts of the country to the seaports at very low transportation rates. Although the country was very small and much of it low and marshy, it quickly gained wealth and power as a direct result of its waterways, natural and artificial, and its skill in trade and commerce.

The rise of England to the position of the first power in Europe in turn was a familiar illustration of the importance of commercial development. Her fleets were sent to all parts of the world. This maritime supremacy enabled her to plant colonies abroad and develop new and lucrative trade routes to America and the Indies. Largely as a result of the wealth thus obtained, her navies came to dominate the world.

Westward the course of the empire has followed the trade routes. The great natural resources of the Americas early created new trade routes across the Atlantic and Pacific Oceans. With the industrial growth of America these have become more and more populous with ships. Take for example the influence of a single product, steel, upon the world trade routes. Great sources of iron ore were discovered on the Great Lakes while similar supplies of coal were mined in Pennsylvania. As a result, the greatest manufacturing center of its kind in the world developed at Pittsburg, convenient to the two sources of supply. The center of the steel industry thus leaped at a bound across the Atlantic from Europe to America.

America's unlimited sources of natural wealth, its ingenuity and enterprise, makes her the richest country in the world. To profit by its vast latent wealth America obviously must develop its harbors and inland waterways. She has the example of Europe's centuries of experiments in building harbors and canals to profit by. If America is to capture and hold her share of world trade, she must successfully meet the intense rivalry of Europe.

The course of empire which has followed, in the main, the great arteries of travel half way around the world has paused in America. It can only be kept here at the price of constant vigilance. It is conceivable, for example, that new sources of iron ore and of coal might be discovered in Asia which, with cheap labor, would make it possible to manufacture steel products so as to undersell America. The world's center of steel might then suddenly jump the Pacific Ocean, as it has jumped the Atlantic, and come to rest on another continent.

CHAPTER III

OUTWITTING THE SEA

ALTHOUGH men have been matching their wits against the sea for centuries in devising harbors to protect their ships, maritime engineering to-day is hardly an exact science. The wind bloweth where it listeth. The currents of the sea cannot be definitely charted, nor storms and tidal waves predicted. The best-laid plans for harbor construction, based on years of observations, may be frustrated in a day by unforeseen moods of the sea. At the best, maritime engineering is a highly complex science.

The battle with the sea is waged most relentlessly in the planning and building of open harbors. At any port, opening directly upon the sea, the problem is baffling. If the port is only a roadstead, a safe shelter for its fleets can be purchased only at the price of constant vigilance. In the type of harbors classified as basins the problem, although somewhat simpler, is often highly complicated. Every possible danger may apparently have been guarded against, yet it is impossible to foresee the strength of the sea.

Before designing an open harbor a careful study is made of the coast and sea bed for a considerable distance on either side of the proposed work. The survey may extend over several years. All the existing currents and tidal effects must be observed and charted under all weather conditions. Special apparatus for making these tidal surveys is employed. The strength and direction of the currents, and their destructive power in years past, becomes a matter of record. The exact amount of silt which has been deposited under various conditions and the extent of the inroads of the sea upon the shore are carefully noted. All possible information connected with the navigation of the coast is gathered from pilots, fishermen and residents of the region.

A detailed record of the direction and force of the prevailing winds in the region is also prepared. The study must also include a record of the height of waves in various storms and their ravages upon the shore line and offshore shipping. Incidentally the recorded force of the wind cannot be accepted as final, since a single gale may spring up in an unexpected quarter and work more havoc than all those which have been carefully recorded. The influence of the wind in relation to the magnitude of the waves, however, is studied in detail. Again many coasts are undergoing constant changes from the effects of unseen currents and the flow of nearby rivers, and all these forces must be considered and a comparison made with conditions many years earlier.

This highly complicated problem the harbor engineer must solve in preparing his plans. It is not strange that his calculations seldom come out exactly right. It is extremely difficult, for instance, to estimate in advance what new currents will be created by the jetties, sea-walls and breakwaters, and the extent of the deposits the currents will leave under new conditions; the formation of bars and unexpected variations in the level of the sea bed often comes as a surprise to the most painstaking engineer.

The barriers erected to outwit the sea are classified broadly as breakwaters and jetties. As its name suggests, the breakwater is a formidable barrier for sheltering a space of water. It may take the form of a pier, but more commonly it is a rough wall of great rocks with a broad base and sides sloping towards the top. It may lie wholly below the surface of the water or be exposed only at low tides. The theory of such breakwaters is that they offer considerable friction to the under sides of the waves, and serve to break them up or at least diminish their force. The breakwater may be built of concrete or stone to offer a smooth surface which the waves cannot take hold of. Breakwaters are generally placed in the more exposed positions to bear the brunt of the attacks of the sea.

The jetty, on the other hand, is designed to assist in various ways to maintain a channel at a harbor or the mouth of a river. They mark the line of the entrance of the channel and particularly divide the smaller waves which reach the shallow waters, while allowing the shore currents to pass along unimpeded. The elaborate works at the mouth of the Mississippi River are an excellent example of jetties. Their main purpose is to guide the river and deepen the channel across the bars, as well as to resist the force of the waves along the coast.

Jetties are built of timber, metal or stone and vary widely in form. They are often formed of a series of timber or iron frames embedded in rubble or stone formations in the bed of the sea or river. The open crib work is often filled with rock. The slopes are pitched at various angles, and the tops are usually raised slightly above the level of the beach. A pier may also serve as a jetty. Excellent examples of jetty construction for maintaining channels may be seen in the harbors of Charleston, Chicago, Oswego, Buffalo and Los Angeles.

One of the most difficult problems in harbor building is obviously to design a safe entrance. It is not enough to build a great barrier which will withstand the severest storms. There must be at all times facility of access, or the fleets cannot enter in time of storm, when they most need protection, while those within may be bottled up in rough weather. There are many things to be considered. The entrance must be so placed as to have an ample depth of water at all times. It is a simple matter to figure on the height of the tides, and the normal depth of water is often effected in this way. In a severe storm a vessel which could ordinarily negotiate an entrance with perfect safety might be wrecked on the threshold of a safe harbor by the curious trick of the waves.

The entrance of an artificial harbor is usually placed at the outer extremity of the artificial barriers set up against the sea. The distance to which the jetties or breakwaters are extended out to sea is usually determined by the depth of the water at the entrance. The opening is either placed facing directly out to sea or pointing in the direction of the worst wind storms likely to arise in the region. A vessel seeking shelter in a storm can thus run directly before the waves, while a ship going out finds its position safer.

This arrangement of having the entrance face the worst gales has several disadvantages. A sailing vessel finds it easier, as a rule, to lay its course straight for the entrance, and once within seek shelter by tacking. The designers of these harbors are obliged to choose between building a harbor which will permit vessels to enter in all kinds of weather or one which will be protected from rough waters within the enclosing barriers.

A complicated problem must be solved in determining the width of the harbor opening. The distance between the outer extremities is usually determined by the size and nature of the channel. If the jetties converge it is usually possible to give the entrance a greater width than in the case of parallel jetties. In several harbors of recent construction the jetties are extended out into deep water in very exposed positions.

Should the harbor opening be too wide a bar is likely to form before the entrance, due, it is supposed, to the action of the scouring currents. On the other hand if the engineer errs in making the entrance too narrow, it induces a rapid current which is dangerous. The current will prevent the formation of bars and insure deep water, but is likely to prove dangerous to vessels passing in and out. The trick in harbor designing is to hit upon a happy medium which will assure a safe entrance in all extremes of weather, free from dangerous currents, while maintaining the required depth.

The walls designed for enclosing a harbor are often merely tentative. The proper width is not definitely fixed, however, until the effect of the tides, currents and wind, obtained in advance, have been actually tested out by experience as the work proceeds.

The effect of the size and exposure of the harbor on wave formation must also be considered. Deep water at the harbor entrance allows large waves to enter and menace the shipping within. Again if the enclosed harbor be too large a high wind may set up dangerous wave motions inside the enclosure. All these factors must be considered. If a channel be formed at the harbor entrance by building jetties the angles of the two walls must be carefully considered. If the jetties converge for a considerable distance the waves are intensified or squeezed together and on entering the harbor are often more formidable than they were in the open sea.

An ingenious plan has been devised to meet this difficulty. The jetty is sometimes built with openings at intervals, so that the waves, on sweeping through, spread out through these apertures and reach the actual harbor entrance with greatly diminished force. Another plan is to build the basin with a shelving bottom just inside the entrance. The wave travels up the channel between the jetties and expends its strength by widening out in the basin.

The action of waves has been studied with the closest attention by scientists in many countries in the hope of devising some dependable method of destroying or diverting their force. Many highly ingenious devices have been conceived with this aim. It may seem a simple matter to calculate the force exerted by waves of various heights in any definite region, but the blows they strike are very deceptive. If one stands at the entrance to some exposed harbor during a storm, as the waves race in from the sea, the problem will be seen to be very complex.

Modern science has made it possible to calculate the force of waves by measuring the depth of the water over which they move, the force of the wind and the distance they travel. All this has been reduced to definite tables, but there are many other factors. The configuration of the coast must be considered; any unevenness in the bed of the sea may exert an unexpected influence and any obstacle in the path of the wave, even if many feet below the surface, may modify its force and change its path. Since the bed of the sea is likely to be unexpectedly raised by the formation of sand bars or deepened by unseen currents, these calculations are often merely approximate.

A mistake in calculating the power of waves has often resulted in serious disaster. In great storms all rules may fail. Amazing tales might be told of sea-walls built on scientific lines with every precaution suggested by modern science to defy the maximum strength of waves which yet have been literally torn to pieces in a few hours by storms.

A variety of wave screens have been invented. One of these consists of a sloping gridiron over which the wave passes. A portion of the water falls through the openings in the gridiron, and the wave movement is thereby checked. It was formerly supposed that waves had no effect at a depth greater than twelve feet below the water of spring tides, but their power was doubtless underestimated.

A highly ingenious plan for breaking up wave action has been devised by an American engineer, Philip Brasher. After a careful study he decided that the most effective way of destroying waves was to attack them in their early undulating stage by forcing a stream of air from beneath. A trial was made at El Sequedo, California, when a system of perforated pipes were laid in the sea. Two pipes some three inches in diameter were run seaward for a distance of 145 feet, separated by a distance of 120 feet. The test was made in a violent storm when waves from twelve to fifteen feet high swept over the pipes. The air forced through the pipes, it is reported, successfully broke up the waves to such an extent that they did not jar the wharf on reaching shore. The cost of operation was trifling. The cost of installing the apparatus is but one tenth that of building a breakwater. The system is now in successful operation both in America and Europe.

The effect of the form of enclosed harbors upon waves has also been observed with great care under a variety of storm conditions. When a powerful wave has once passed through the entrance and expanded to the full width of the harbor it still continues to exert considerable force. Various experiments have been carried out in varying the form of harbors with a view to reducing the wave force. Many harbors are especially designed with this object in view. If the harbor expands within the entrance to a considerable lateral width it usually is much more tranquil. Any extension of the harbor seaward, however, has little effect upon reducing the force of the entering waves.

The forms of the harbors of Chicago, Oswego and Buffalo are especially favorable for stilling the waves which enter through the lakeward entrances. It may be laid down as a general rule that harbors, unless they be effectively screened and sheltered, are themselves liable to act as wave generating areas. The narrower the entrance as a rule the better is the protection from without.

An interesting study has been made of the exact manner in which waves act upon any fixed obstacle in their path. When a wave strikes against a wall standing vertically in its path it deals a complicated blow. The portion of the wave in contact with the wall moves up and down through a distance equal to twice the height of the original wave. At a point midway between the trough of the wave and the wall, the water moves back and forth horizontally. The force exerted by this action is very great. Any one who will watch the waves striking against a sea-wall or bulkhead will notice this action. When, however, a wave does not meet an obstruction and advances rapidly into shoaling water its force is rapidly decreased. The best plan of counteracting the striking power of a wave it seems is to introduce friction from beneath. The crest of the wave then falls forward and the force of the impact is quickly decreased.

In designing breakwaters the great problem is of course to build an obstruction which will successfully withstand the hammering attack of the waves. These walls of defense are the most important features of any artificial harbor. The problem is much more complicated than the layman imagines. No other form of construction raised by man is exposed to such relentless battering. The waves are a thousand times more destructive than the force of the wind or rain. Upon the stability of these sea breakwaters and their ability to break up and dissipate heavy seas depends the safety of helpless vessels and incidentally the movement of commerce.

The wind, waves and currents play curious tricks with the barriers set up against them. One plan of outwitting the waves is to build two breakwaters projecting from the shore some distance apart and converging at their extremities. An opening for vessels to enter or leave is made just wide enough to give safe clearance. Such a plan has been followed with success in the artificial harbor at Oswego.

Another plan is to build the harbor with two entrances. Two breakwaters are carried out from shore and a third detached breakwater is built between the outer extremities of the two. Two entrances are better than one for obvious reasons. The direction of wind and waves may render one entrance very dangerous, while the second has some measure of protection. The best illustration of this form is to be found in the great artificial harbor of Buffalo on Lake Erie.

The entrance to the artificial harbor of Chicago on Lake Michigan solves the problem in still another way. A detached breakwater is here placed before the entrance to the harbor in such a way that the approaching channels are protected and at the same time it forms an outer harbor. The problem in these designs is to provide sufficient protection against the storms no matter from what direction they may come. The sheltering arms of the breakwaters and jetties are designed to resist the maximum forces which may be directed against them.

A great harbor has been built at Galveston with an entrance 8,500 feet in width or more than a mile and a half. The finest jetty harbor in the world is probably that of Charleston, South Carolina. The entrance in this case is but 2,000 feet in width. The difference is due to the different conditions encountered. In determining the width of the entrance between the jetties it is also necessary to consider the rise of the tide in relation to the tidal area enclosed by the jetties. If a river empties into the artificial enclosure the exact volume of fresh water discharged and the force of the current must also be considered. The requirements of the trade of the harbor, the number of ships calling there, and their draught must also be considered. Many considerations enter into the extremely complicated problem that the engineer must solve before deciding on the length and size and design of his harbor.

All harbors are more or less seriously menaced by the formation of bars. Despite the advance in the science of harbor building these barriers remain more or less a mystery. Many ingenious works have been devised to combat them, often with success, but they are still one of the most baffling problems in hydraulic science. A harbor may be crowded with commerce but if its channel be closed by a bar its activities are brought to a standstill.

Many of us at an early age have carried on experiments in elemental hydraulics in the clear shallow waters of ponds or streams by building little dams or jetties to divert the miniature currents. If the current passes quickly over loose sand it may be seen to dig out a new channel, while on spreading out and slowing down it has often formed a tiny sand bar. If the experiments be carried further and the action of the water watched more closely it will be found that the action of the little currents is surprisingly complicated.

Although the action of rivers on entering the sea has been watched for centuries the formation of the bar is still much of a mystery. There are several theories to account for these deposits. One is that a river in its journey to the sea washes away an immense amount of sand and earth which it carries along for great distances. At its mouth the stream spreads out and diffuses itself as it enters the sea. It therefore loses its velocity and drops the sediments which it has held in suspension while moving more rapidly, and thus a bar is formed. It has been found that silt carried by fresh water is released and deposited on mixing with salt water.

Some hydraulic engineers believe, on the other hand, that the bar is formed by the meeting of conflicting currents which, in joining, form slack water, when the silt is dropped to the bed of the river or sea. Still another theory, which is the more generally accepted, attributes the formation to the action of tidal currents and storms. Whatever may be the cause, the position of bars and channels often change for no apparent reason. This roving disposition of bars at harbor entrances is at times the despair of hydraulic engineers.

The formation of bars is so formidable an enemy that every resource of maritime engineering has been employed to fight them, and enormous sums of money have been expended in building systems of jetties and sea-walls. One plan is to build jetties running out into the sea which narrow the channel of the river until it reaches deep water. The theory of this construction is that the river will thus continue to flow so rapidly that it will carry along the silt it holds in suspension until it is past the harbor entrance. Another plan is to build jetties or sea-walls at strategic points in the harbor so they will change the movement of the currents about the harbor entrance. The action of the current is carefully observed and the depth of the water measured over a wide area, and the position of the jetties or breakwaters which are to change these currents is carefully studied. After the walls have been constructed, perhaps at the cost of millions of dollars and years of labor, they may fail of their purpose. Despite the advance of maritime engineering the currents of the sea, like the winds, flow where they list.

The engineers always have recourse to the expedient of dredging away the bar. It is only by a constant vigilance and the expenditure of vast sums of money that New York harbor, for instance, is kept open to its great fleets. When Hendrik Hudson first entered New York harbor in 1609 he found the water scarcely deep enough to accommodate his small craft, and was obliged to send ahead row boats to sound the channel. There are at present six great channels entering New York harbor, the deeper of which accommodate the largest ships afloat.

If these channels were neglected the sand would quickly find its way in, and shipping would soon be seriously menaced and in time the harbor would be closed to large ships. Any one passing up or down the New York harbor will notice the powerful sand dredges at work widening and deepening the channels. The sand is drawn from the bed of the channel by a powerful suction device, and deposited in scows alongside to be carried to a safe distance for dumping. Similar crafts are familiar sights in the channels of most of the great natural harbors of the world. An endless battle must be waged if the insidious encroachment of the sand is to be held in check.

The builders of harbors from the earliest days have fought a common enemy in the animals which attack the submerged portions of docks and similar structures. There are a great many boring animals in the sea which work such destruction. Their ravages are frequently mentioned even in early Greek and Roman literature. Their slow but insidious attacks are often more to be feared than the most violent storms, and since the attack is often dealt far below the water it is extremely difficult to resist. Millions of dollars' worth of property have been destroyed in this way.

The marine boring animals have been studied in great detail. The most familiar forms are supplied with two minute shells, forming part of their heads, which do the actual boring. The edges of these shells have minute file-like teeth which are rasped back and forth by an ingenious muscular machine. The scratch which such a movement makes upon a piece of hard wood is at first almost microscopic, but when repeated millions of times the hardest wood is gradually worn away and the little animal slowly bores a hole equal to the diameter of its body, slowly working its way through the toughest wood. Remarkable examples of this action have been observed in the past few years in San Francisco harbor, where elaborate investigations have been carried on.

Countless plans have been designed for combating these attacks. The commonest precaution at present is to impregnate the timbers exposed to such attacks with creosote or some other chemical which will discourage the borers. Another plan is to encase the timbers in a thick covering of concrete or even employ concrete piling and cross pieces. Despite these precautions the boring animals still continue to be a menace.

A borer has made its appearance on the Pacific coast, especially in the harbor of Los Angeles, which actually cuts its way through concrete. This new enemy of wharves and under-sea construction is a rock-boring mollusk, a trifle larger than a man's thumb. Examples of its work, discovered in Los Angeles harbor, seem almost incredible. The borer, measuring over an inch in diameter, has in some instances cut a hole large enough to hold its body for a distance of nearly three inches through solid concrete. It had been thought that the use of concrete for piles and other submarine construction solved the problem of the borers, but the newly discovered enemy destroys this hope. The rock-boring mollusk does not attack wood.

To the Government of course falls the task of surveying our interminable coast line, and measuring the depth of channels. Upon the accuracy of these surveys must depend the safety of the great fleets which bear the commerce of the world to and from American shores. The task is far more difficult than the landsman imagines. No other country faces so complicated a problem. The floor of the sea about the coasts, as well as the channels of inland waterways, are constantly changing.

Three types of surveys are made by the Geodetic Survey which is entrusted with this work. The first is a rough reconnaissance with little attention to details. It is employed when time presses, the region is little frequented and the general conditions are obvious. When a more accurate knowledge is required soundings are carried out by means of a lead and line. This method, when painstakingly executed, is very accurate for surveying almost every form of ocean or river bed. It may fail, however, if the bed has pinnacle rocks. It is always possible that some such rock may be overlooked. A marine survey, which must be the guide of shipping, like a chain, is only as strong as its weakest link.

To obtain absolutely dependable results the surveys made with lead and line are supplemented by dragging a wire over every foot of the submerged area. The method employed is very simple in principle, but when hundreds of miles of coast must be surveyed in this way in the face of possible storms, the work is often extremely difficult. The apparatus consists of a horizontal wire which is literally dragged over the bed of the sea. It is held in a horizontal position at any desired depth below the surface by means of an arrangement of weights and adjustable upright cables which extend up to the surface of the floats.

The apparatus is towed over the area to be surveyed by two launches, one at either end of the wire. As the wire is dragged through the water it will naturally catch upon any object which rises above it, and the exact location of any obstruction may be mapped. The depth of the obstruction is then obtained by sounding with a lead line from a small boat. In regions where the sea currents are constantly shifting the sand and piling it up in bars it is only by constant vigilance that dependable surveys may be made.

Despite the frequent surveys made in New York harbor a pinnacle rock long eluded the surveyors and its presence was discovered only a few years ago. The rock rose from the bed of the harbor at a point only a few feet from shore near the Battery, the southernmost point of Manhattan Island, in the heart of the busiest harbor in the world. Countless ships had passed it, in more than two centuries, without mishap. One day when the water was unusually low a vessel of considerable draught chanced upon it and suffered serious injury. The Government lost no time in removing it.

Constant observations are also made of the course of currents and their rate of flow. Vessels are often carried past their destination or are seriously retarded by currents, to the consternation of the pilots. Like the winds the currents of the sea frequently change and their origin and destination remain a mystery. The principal currents along our coast have long since been mapped, but they are constantly changing their courses to the despair of the chart makers. One plan of measuring currents is to throw overboard a number of bottles containing identification papers. All vessels on their course are requested to pick up such bottles and report them to the Government. An immense amount of valuable information has been collected in this way. Bottles thrown into the sea off the coast of America have been picked up off the coast of Europe. In this way the rate at which the currents move is often obtained with considerable accuracy.

CHAPTER IV

AMERICAN HARBOR PROBLEMS

A GREAT ocean freighter was recently loaded in New York harbor with a cargo destined for a distant South American port, when, just before the sailing hour, it was found advisable to withdraw the steamer. It was thereupon discovered that the cost of unloading the cargo and transferring it a distance of sixty feet on the dock would equal the entire expense of carrying it 5,000 miles or more to South America. Obviously any labor-saving device which will reduce the cost of handling cargoes and facilitate the "turn around" of ships is a vital factor in shipping.

The crux of the harbor problem often lies in transhipping cargoes. A harbor may offer every natural advantage for shipping, but it will fail to attract commerce and hold it, if it lacks in equipment. Several ports of entry may compete on equal terms for trade, but commerce will eventually flow to the port which offers the more efficient means for cargo handling. It often happens that harbors off the beaten track of travel will outgrow rivals much more conveniently situated because of their superiority in port equipment.

The problem is a very simple one. Every vessel represents a considerable investment. The wages of the crew add up very rapidly. It costs thousands of dollars a day in wages, interest on investment and operating expenses to keep a modern freighter or passenger steamer in commission. Every hour saved in unloading such a ship and reloading, coaling, provisioning and preparing her for sea has, therefore, a definite value. The additional expense entailed in holding a vessel in port for a few days, even hours, when thrown into the balance, may turn the scales in favor of loss rather than profit for the venture.

The problem of cargo transfer has been

studied by modern efficiency engineers with the most anxious attention. Since the profit or loss on a shipment may be decided in the short distance between the ship's hold and the dock the battle between rival harbors to secure trade is often waged there. A busy ship is one of the most interesting sights in the world. The whir and shriek of the machinery, the rapid movement of the cargo, whatever it may be, the bewildering but orderly progress of immense quantities of material in and out of the ship, offer a fascinating spectacle. The scene will gain new interest when it is realized that the growth of ports, perhaps the future of the cities spread about them, is being fought out in this narrow field.

It is a simple matter to load or unload the old type of freighters, however spacious their holds, if there be only a single deck. In the great modern multiple-deck vessels the problem, however, grows very complicated. Some of the new ocean liners have as many as eight decks for stowing cargoes. The unloading and reloading of such a ship is much the same as removing the contents of an eight-story loft building, without the use of elevators, through a hole in the roof. The main difficulty lies in there being such limited space for the use of machinery of any kind. In raising or lowering thousands of tons of freight this vertical distance very complicated tackle is required. Despite all the improvements in dock machinery much of this work must still be done by hand. A rich reward awaits the ingenious engineer who will hit upon some method of solving this problem.

When the cargo can be carried through ports in the side of the vessel the work of transhipment is, of course, greatly simplified. The movement of freight then becomes horizontal and can be handled by trucks and conveyors of many forms. Each deck can then be reached by adjustable ramps or gangways. Such cargoes as sugar or bananas may be loaded by a continuous-motion mechanism without being touched by hands. The cargoes, when being handled automatically, are often weighed while in motion, so that the continuity of the operation of loading or unloading is not interrupted.

In analyzing the problem of cargo transhipment the work of unloading a vessel is generally divided into four distinct operations. Let us assume that a modern vessel with its hold filled with a mixed cargo lies beside a dock ready for unloading. The first operation is known as "breaking out." This consists in moving the cargo from its place in the ship's hold to a point directly beneath the hatches, to the nets or tackle of whatever form used for raising it, or to the opening in the ship's side through which it will be transferred.

The second operation comprises the hoisting from the hold and transfer to the dock or to the lighter which has been brought alongside. In handling some forms of cargoes immensely complicated machinery is required for this work. The operation of hoisting ends when the ship's tackle, or whatever the machinery may be, deposits the cargo on the pier or lighter.

The third movement of the cargo is conveying it from the place where it has been deposited alongside the ship to the point where it is to be stowed. In the simpler harbors this labor is usually done wholly by hand, or rather by the backs of the men who work the cargoes. The machinery employed in most modern harbors for this work is amazingly efficient. Millions of tons of freight must be transferred by mechanical means. One of the most interesting features of this equipment are the gasoline or electric trucks or miniature trackless trains employed in the work.

The fourth operation in working cargo is the stowing. This includes the placing of freight on piers, lighters or railroad cars. Every one knows what skill may be employed in the simple operation of packing a trunk. When millions of tons of assorted freight cargoes are to be packed away, with due economy of space, the problem becomes an exact science. An interesting feature of this work is the tiering or stowing away of freight several tiers or stories high. Much ingenious labor-saving machinery is employed for the purpose.

The loading of a ship is similarly divided into four general operations. First comes the "breaking down." The movement of freight from its place of storage on a pier or lighter to the conveyor which is to transfer it to the ship's side is included in this operation. The work is done by hand or by truck operated by hand or electrically. It is usually the reverse movement of the third and fourth operation of unloading. The movement ends when the freight has been brought within reach of the ship's tackle.

In some cases no intervening operation is necessary. When the prospective cargo must be transferred for a considerable distance the trucking or carrying is classified as a distinct operation. The third operation includes the hoisting over the ship's side and lowering into the hold, or the transfer through openings in the sides of the ships. The last operation consists in "stowing" or placing the cargo in position in the hold of the ship. Since space aboard ship is very valuable considerable skill is required for this work.

In working cargo on small boats all eight operations of loading and unloading may be performed by the human machine. The cargo is raised piece by piece to the height of a man's back and laboriously carried over the ship's side. The commerce of the world was carried on in this primitive manner for centuries. It is only in comparatively recent times that even the simplest forms of dock machinery have been employed. In a single generation the development of time- and labor-saving machinery for handling cargoes has been greater than during many centuries.

An important forward step was taken by the invention of the first dock crane. Although its early forms were very primitive, it did the work of many men with an important economy of time. The simpler cranes were worked by a creaking windlass turned by hand. The development of the crane in a comparatively few years has been astonishing. To-day most cargo-carrying ships have their own booms, permanently mounted on deck, which may be operated by steam or electricity. On the great freighters these booms are often very powerful and are capable of handling any piece of cargo the ship may carry. The modern type of freighters carry a battery of these booms so placed that one or more can operate in each hatchway, or reach far overside in range of the side openings. An up-to-date vessel with all these booms in operation loading or unloading cargo is a very busy spectacle.

Many modern docks are equipped with highly complicated and powerful cranes for working cargo. There has been a remarkable development of the crane or derrick of late in American ports. There are to-day three general types of cranes employed in American harbors, the locomotive or traveling crane, many ingenious forms of cranes installed on the docks, and the floating cranes. The locomotive crane, set upon a regular eight-wheel car-truck, is employed as a rule on open docks in the vicinity of shipping.

It is a very elastic unit since it can be run readily on tracks beside the cars to be unloaded, or on the outer edges of docks within easy reach of vessels. The arm of the crane may extend far out from the tracks and be readily swung through a wide arc. It can thus pick up the freight from incoming trains and swing it within reach of the ship's derricks.

A variety of forms of overhead dock cranes have been devised for handling special cargoes. They may be stationary, with long arms which reach out far over the docks or the ships' sides, transferring immense weights with surprising ease and rapidity, and drawn back when not in use. The crane again may travel back and forth along tracks or galleries on the docks, picking up cargo from a vessel and depositing it on another dock or reversing the operation. A single workman may do the work of a gang of dock-hands, guiding his cranes by merely touching a lever. The latest cranes are of the revolving jib type, equipped with traveling, slewing, luffing and hoisting motors which are amazingly flexible, often handling packages of twenty tons weight.

One of the most ingenious of these cranes is the giant electric magnet used for loading and unloading iron. The magnet is a great disk some eight feet in diameter which may be lowered or raised and swung through a wide arc. It is lowered upon the iron when, on the closing of a switch, it instantly becomes a powerful magnet which attracts the metal and holds it fast. The disk with its metal load is then raised and swung to any desired point, perhaps over the deck of a ship, even lowered to the ship's hold. When the current is shut off the magnet releases its load.

Many American ports are equipped with powerful floating cranes which lend invaluable assistance in cargo handling. They are employed to handle freight which is too heavy to be raised or lowered by the regular ship's machinery or the dock derricks. A single company in New York harbor employs twenty-four such cranes, some of which will handle objects of 150 tons weight.

It is pertinent in this connection to refer to the criticism often directed against American dock machinery of this class. It is pointed out that the cranes on the docks in several foreign ports, notably at Hamburg, are much superior to those found in American ports. But American ports, as a rule, face a different problem from those in Europe. A large proportion of the ships carrying cargoes to and from American ports are equipped with efficient booms which work their own cargoes and render expensive dock cranes unnecessary. The floating crane, so familiar an object in American ports, is also an important factor.

The American ports where special cargoes of coal, cotton, ore or grains are handled have developed systems of elevator machinery which are unrivaled anywhere in the world. The mere recital of figures fails to impress one. The photographs reproduced here visualize the remarkable development of this form of port machinery. Take for illustration the powerful yet nimble dock machinery employed for loading coal.

(Facing Page 96.) A steel coal-car carrying seventy-five tons of coal is raised by this device and tilted over until its entire contents are emptied. The coal flows by gravity into chutes, which are adjusted directly above the holds of a vessel. The mechanism can handle sixty full-sized coal cars an hour or at the rate of one a minute. The back-breaking labor of shoveling a single ton of coal into the household bin may serve as a unit of measure in judging the efficiency of this device.

There has been of late an amazing development in America of the conveyor type of loading machinery. The endless belt or chain, or some ingenious combination of the two, performs a large part of the labor of handling cargoes. They are employed to raise cargo of many kinds to the level of the ship's deck or of the openings in the ship's sides. The elevating device may be portable and be rolled about the deck of a ship or a dock to any desired position. One of the most familiar forms of this apparatus is that used for loading luggage upon passenger steamers. It consists of an endless belt, moving rapidly from the dock to the ship's deck. A variety of objects, suit cases, trunks and the like, are simply laid on it, and a moment later are deposited on the ship's deck. Similar devices equipped with buckets are used for coaling or handling grains.

The familiar hand truck has also undergone an interesting evolution. The labor of scores of stevedores is now done quickly and efficiently by a single electric motor truck. These are to be found on docks in American ports to-day in surprising variety. There are trucks designed for handling only trunks and light luggage, which trundle heavy loads along the docks at surprising speed. Similar forms are designed for transporting much heavier objects. A small crane is often placed at the front of the truck, operated electrically by the driver or chauffeur, which will pick up objects weighing several tons and swing them on or off by merely touching a switch. These motors are also used to haul miniature trains of six or eight trucks. They are extremely elastic, backing and picking up their trains and discharging them with remarkable facility.

Another ingenious development of the familiar truck is the electric tiering machine. As its name suggests the device is used for raising heavy boxes and packages to set them one atop another in tiers, thus saving valuable space on the docks or in the ship's hold. The old plan in handling such packages was to employ several men to laboriously lift them to the desired height. The tiering machine is operated by a single workman and is readily rolled about the floor of the docks or the decks of a steamer. By merely closing a switch, powerful machinery is set in motion which raises a heavy packing box, for instance, to the height of the tier on which it is to be placed. The work of scores of men can be performed by a single machine with an important economy of time. A photograph of one of these tiering machines in operation is reproduced on page facing page 81.

In modern harbors the most familiar craft is the lighter. These craft appear in a great variety of forms, varying from small open boats to efficient steam-propelled vessels of elaborate design, carrying powerful machinery for working cargoes under various conditions. The derivation of the name is obvious. The lighter was used originally to lighten the ships of their cargoes that they might pass over dangerous bars. In many harbors the lighters are the only means of communication between ships and shore.

No other means of transferring freight is as flexible as the lighterage system. It has proved to be more economical than any form of carrier in handling loads up to fifty tons in weight. In competition with carts or railroads lighters continue to hold their place. Even when efficient modern belt line railroads have been built the lighter does not disappear from the harbors. The lighter in some form has been employed for centuries and probably no improvement in port machinery will ever wholly take its place.

The harbor lighter, the world over, takes one of three general forms—the simplest de-

A TRACKLESS RAILROAD FOR HANDLING FREIGHT

DOCK LOADING MACHINERY ON THE GREAT LAKES

Photo by Irving Underhill

AN AUTO DOCK CRANE IN OPERATION

A TIERING MACHINE IN ACTION

sign with an open deck, the covered deck scow, and the open hatch scow. Each general type has scores of variations, to suit special demands. A great change has come over the form of harbor lighters in the last twenty years. In American waters the lighter was formerly a small sloop pointed at the bow, equipped with sails. It was usually designed to carry about ninety tons of freight. To-day in most American harbors the lighter almost always carries over 300 tons and many of them up to 600 or 700 tons of freight. The most recent development of the craft is the steam lighter, equipped with derricks and tackle operated by steam or electric power.

The system of lightering developed in New York harbor is doubtless the most complete of any harbor in the world. At present sixty-five per cent. of all the freight handled in New York harbor, exclusive of interchange, is carried by some form of lighter. Much of this is taken from ships to be carried to other ships, to the railroad terminals or to docks for general distribution by trucks. Because of the curious geography of New York harbor the lighter is at present the cheapest and most efficient method of transfer. It takes the place of the belt lines which prove so indispensable around most harbors. The system is nevertheless essentially faulty.

The labor-saving machinery used for loading and unloading grains has had a remarkable development in American harbors. It must be remembered that no other commodity plays so important a part in American shipping to-day. The presence of wheat attracts great fleets of ships from the furthermost corners of the world, and prosperity of great ports and their rise to importance or their decline are largely determined by their ability to deliver this grain. The competition between many American ports for the wheat trade is at present especially keen. Several cities along the Atlantic coast are in a great race to offer the best facilities for handling wheat and the rivalry is being anxiously watched. The next important development in the wheat trade may be the transfer of

New York's supremacy as a wheat port to some other Atlantic port with all that this implies.

In the fight for the grain trade the weapon used by the rival boats is the complicated machinery employed for loading and unloading wheat. If a new device can be invented which will reduce by the fraction of a cent the cost of loading a bushel of wheat, it becomes a valuable factor in this warfare. The handling of wheat is a far more complicated affair than is generally imagined. The grain must often be cleaned, cooled, dried, mixed, clipped, sampled and weighed and bagged during the process of transhipment. The machinery for doing this work on an enormous scale is highly ingenious.

The wheat is usually handled by means of great elevators built upon vessels of various forms. Some of these steam about the harbor under their own power; others must be towed into position. The grain elevator is one of the most picturesque craft in the harbor. Its machinery is protected by an oddly shaped cabin or house usually in the form of a truncated pyramid whose top rises high above the other craft.

In the latest form of elevator the grain is raised by means of conveyors, or by suction pipes, or by both. The grain is picked up from the pits, from freight cars or the holds of barges or vessels, and raised to a considerable height at a surprising rate of speed. Gravity is employed to do much of the work of loading. The wheat is usually discharged through spouts into the holds of vessels or into cars or trucks. Some of the great grain elevators have a transfer capacity of from 10,000 to 12,000 bushels a day.

The great grain ports have facilities for storing large quantities of grain for considerable periods. These elevators are usually provided with the machinery for treating it in various ways. If a cargo of grain, for instance, has been saturated with water there is a special machine at hand for salvaging it, drying it and, when it is dried and cleaned and weighed, bagging it, all by mechanical hands.

The average person is surprisingly ignorant of the comparative cost of land transportation and the expense of loading and unloading freight. A ship at sea seems to move very deliberately compared with the enormous distances it must travel. A freight train on the other hand goes on its way at a comparatively high speed. The work of transhipping cargo again does not appear to be a very expensive operation. The relation of the cost of transportation by rail or water and of transhipment comes as a great surprise.

The use of some labor-saving device for loading or unloading on the docks may readily save an expense equal to thousands of miles of steaming. The cost of bringing a ton of freight 250 miles to the coast may again be greater than that of carrying it to a distant foreign port. The cost of storing freight is a very important consideration. It was found recently that it would be cheaper to carry freight by sailing vessels from New York around South America to California and back again than to pay storage on it for the same length of time in New

York city. Since it is necessary to store immense quantities of freight in our harbors the warehouse problem becomes very important.

The problem of providing cheap storage in harbors is very ancient. In designing modern harbors special attention is paid to the construction of warehouses and their relation to the general cargo movement. Many of the early harbors were very badly served in this respect. The only shelters provided on or near the docks were often rough sheds of wood which soon became dangerous firetraps. The space for storing cargoes was, as a rule, badly placed and ill designed, necessitating an immense amount of lost motion in transferring merchandise. Warehouses of some form have been found in harbors since remote antiquity, in the harbors of the Phœnicians, Romans and Greeks, but it is only in comparatively recent years that the builders of harbors have realized the opportunity here offered for expediting the handling of cargoes.

Freight of many kinds, destined for incoming ships, is usually brought to a port by boat, train or motor truck and is discharged on piers before the time for loading. The goods may change hands while in port, and be sold many times. Designers of the old-time piers failed to recognize the difference between providing extended storage or temporary shelter for cargoes. Warehouse facilities were rarely provided within easy reach of the docks and the steamers. In the recent development of the pier, upper stories are often provided for such storage.

The warehouse is often conveniently placed at the waterfront so that cargoes may be transferred directly from the ship to the building by a single movement of the derricks and cranes, or by a horizontal movement of freight conveyors. When the warehouses must be located at a distance the transfer of freight is facilitated by belt-line railroads. An ingenious substitute for the standard track road is an adjustable loop monorail system. Motor trucks designed for handling special cargoes are much used and a great variety of scientific cargo-handling devices are now available.

The great European harbors are, as a rule, well equipped with warehouses scientifically designed and placed. They are often built directly facing the docks or wharves. The walls of the building sometimes rise directly above the sea-walls which form their foundation. It is thus possible to transfer cargo which has been raised from the ship's hold directly to the warehouses by simply swinging the ship's derrick outboard. In several European ports great attention has been paid to designing these buildings to render them both useful and ornamental. Some of the modern warehouses of Holland might serve as art galleries or museums. They are built of stone, well proportioned and often with elaborate façades. The warehouses of recent construction in American harbors, although lacking in architectural distinction, are extremely well placed and well designed for the work they must perform.

The money expended in harbor development and maintenance seems fabulous. To justify the spending of such sums the return from the shipping attracted must be enormous. Since the World War, the sums devoted to harbor building in America have surpassed all previous records. Great as have been the outlays in America the money spent in port development abroad has been even more remarkable. An interesting comparison is afforded by the following list of expenditures for port development here and abroad, at various periods.

New York City	1870 to 1907	$89,000,000
Glasgow	1860 to 1909	44,000,000
Liverpool	1850 to 1902	150,000,000
Newcastle-on-Tyne	1860 to 1909	85,000,000
Hamburg	1860 to 1909	100,000,000
San Francisco, recommended ..	1901	50,000,000

CHAPTER V

GATEWAYS OF THE ATLANTIC

THE great focal points of the trade routes of the world lie at present along the eastern seaboard. A vast fleet of ocean-going crafts carrying annually freight valued at over $5,000,000 regularly visits our harbors on the Atlantic. The wealth of the commerce of our other coasts is much less. During the World War many of the old established trade routes were deflected to our eastern seaports. A keen competition has naturally developed among these coastal cities in bidding for these rich prizes. If our harbors be properly developed to handle this trade an unprecedented profit may be gained and held in the future.

The rise and decline of the great ports of the Atlantic has often been caused in the past by unforeseen accidents of trade. The commerce of Boston was dealt a severe blow by the disappearance of the whaling industry. The development of New York to the greatest of the world ports was not anticipated by the shrewdest merchants of an early period. New York rose to power largely as the result of the influence of a narrow channel of water out across the State, known as the Erie Canal.

Philadelphia once easily dominated the commerce of the Atlantic seaboard, and the loss of her trade to New York was not foreseen. Her valuable Chinese trade has completely disappeared. Charleston enjoyed a profitable trade with many foreign countries which was destroyed at a blow by the Civil War. When the commerce of the world first flowed in large volume to our eastern ports, it was carried by the famous clipper ships. These picturesque craft could outsail anything afloat under any flag. It seemed incredible at the time that they would be driven from the seas by the new-fangled invention, the steamboat.

One fourth of the world's wheat is produced to-day in the United States and Canada. The stream of wheat exportation has flowed most freely from New York. This has been largely due to the fact that many foreign vessels coming to New York have small return loads, and therefore fill up with cargoes of wheat. To-morrow the situation may be changed. New York has also enjoyed a great advantage because of its remarkably efficient railroad connections with the wheat-growing areas. The times, however, are critical. The United States may lose a large part of its valuable wheat trade, perhaps forever. America consumes a larger part of its wheat supply to-day than formerly, and the world depends less upon the United States for its wheat than in the past.

Several of the eastern ports of the United States have been built up largely by sending wheat to Europe, and importing immigrants from Europe, in turn to grow more wheat. Meanwhile the exportation of food-stuffs from Canada to Europe is growing. The list of changing conditions might be continued indefinitely. Obviously the future of the great ports of the Atlantic is dependent upon many chance factors. The prophet who attempts to foretell the future of the commerce of the Atlantic seaboard may err as widely as did the merchants of a century or less ago.

No two of the port problems along the Atlantic seaboard are identical. Each port must be developed and equipped to meet the particular demands made upon it. They cannot be standardized. One port needs an elaborate provision of warehouses; another requires chiefly efficient machinery for transhipping cargoes. The docking facilities required for various types of commerce differ widely. One port must expend a fortune to maintain open channels; another is relieved of this problem, but must develop a system of breakwaters, jetties or bulkheads at enormous outlay.

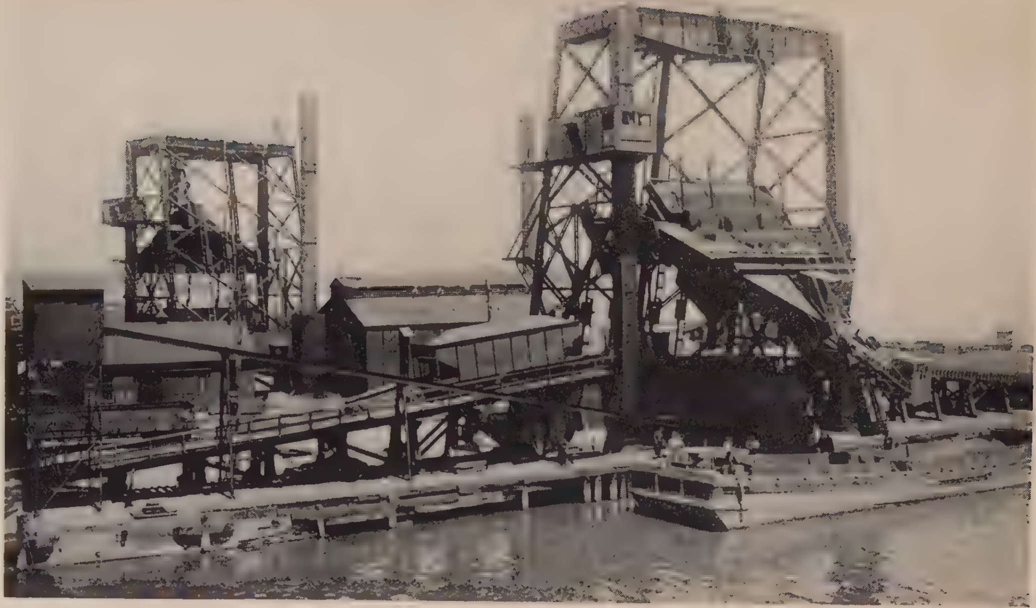
An expensive harbor does not necessarily make a port which will attract commerce and wealth to a city. The need for better ports in America is more imperative than is generally imagined. The great problem faced by rival ports on the Atlantic to-day is to provide harbors and machinery best suited to the types of ships which visit them, and there is unprecedented activity in all these ports to enlarge and improve the accommodations for shipping.

Until a decade ago, great rivalry existed between shipping lines of different countries in building large ships. It was predicted that ships would eventually be built with so deep a draught that many harbors would be closed to them. To-day the tendency is to build smaller ships. The day of the great 50,000 ton liner is past. As a result the channels of the great harbors of the Atlantic are deep enough to accommodate all types of foreign and domestic ships. In building harbors to compete for the foreign shipping, the problem of providing extremely deep channels of forty feet or more need no longer be considered. The ingenuity of maritime engineers is now being directed to provide extended waterfronts and adequate docking facilities as near as possible to tidal streams. The problem of providing railroad connections is also being studied as never before.

The dark horse among the Atlantic ports to-day in the race for the great prizes of trans-Atlantic trade may be Montreal. Although New York with its great volume of shipping seems assured of the first position on the Atlantic seaboard for generations to come, a large share of her commerce and that of other coastal cities may be deflected to the Canadian port. Montreal is obviously handicapped by lying a thousand miles from the sea, and by her northern latitude, which closes her port for several months of the year. On the other hand she stands on a great waterway, linking the Atlantic with the Great Lakes, and will profit by the incalculable commerce which will flow back and forth through this channel.

Montreal is the chief doorway of the outgoing and incoming trade of Canada. More than one third of all the importations of the Dominion enters through her harbor. Her position at the head of navigation on the great waterway is very favorable. To-day more grain is shipped from Montreal than from any other port in North America, with the exceptions of New York and New Orleans. The original eleven-foot channel of the St. Lawrence River at this point has at great expense been deepened to thirty feet at low water.

Within a few years great fleets of seagoing vessels may take on cargoes of wheat in the ports of the Great Lakes, pass through the St. Lawrence Ship Canal and proceed directly to Europe. There may be an important economy in following this route. The time and expense entailed in transhipping wheat, even with the aid of the most efficient elevator service, would be greatly reduced. A direct route will thereby be opened from the grain producing regions of Canada to the open sea and to European markets. The American farmer may find himself brought in direct competition with the Canadian farmers who formerly must ship their wheat through American territory. In other words Canada will be able to ship its wheat to



LOADING COAL AT THE RATE OF A CAR A MINUTE

A TYPICAL NEW YORK DOCK SCENE

Europe more cheaply from its great producing areas than can America from her wheat belt.

The facility with which wheat may be handled may have an important effect upon this movement. The ships used on the Great Lakes for transporting grains and other special cargoes are doubtless the most efficient of their type in the world. They have been designed so successfully for their special work that no other carriers can compete with them. These ships, however, are not well suited for ocean navigation. Even if a great ship canal be constructed connecting the Great Lakes with the seas by way of the St. Lawrence, it is thought unlikely that the lake craft will venture upon the Atlantic to foreign ports. At the same time the deep sea craft cannot successfully compete in this trade with the specialized lake steamers.

The machinery now available for transferring cargoes of wheat from one ship to another or from a ship to the docks and again loading upon another ship is to-day so efficient that it may be found cheaper to make the transfer from one type of craft to another than to make the entire journey from lake ports to Europe, or the reverse, by the same vessel. In other words the docking facilities and the modern machinery available for transferring cargoes of wheat may have a far-reaching influence in determining the future of world trade routes. The all important decision as to whether New York or Montreal is to hold the highly lucrative grain trade of the country in the future may be determined by the efficiency of the harbor development of the two cities.

The harbor of Boston enjoys several obvious advantages, as regards its contour and its position, over Montreal, New York and other great seaports to the south. While New York lies 3,056 miles from Liverpool and Montreal 2,972 miles, the distance to Boston is but 2,862 miles. In other words a vessel can make fifteen trips between Boston and Liverpool while it would be making but fourteen between Liverpool and New York. Boston sits close to the sea, while New York is two hours' sail from the Atlantic, and

Montreal lies 1,000 miles inland. Then again Boston is not troubled with sand bars and shifting channels as is New York. Still another advantage is that freight may be carried from some ports of the west more cheaply to Boston than to New York.

A century ago the commerce of Boston was equal to that of any port in America and her ships were familiar in many distant harbors. Her whaling ships sailed around Cape Horn and ventured out upon the unknown waters of the Pacific to return with rich cargoes. The skill of her sailors became famous around the world. For a long period the fleets sailing from Boston, despite keen competition, carried a large share of the nations commerce. In 1840 Boston was selected as the American terminus for the Cunard Line, which was the first of the trans-Atlantic lines. The ten years which followed were the most active in the commercial history of the city. By 1869 this great trade had dwindled, and in that year not a single vessel sailed from Boston for a foreign port.

The history of Boston commerce affords an interesting object lesson in port development. A modern port must be more than a fine natural harbor. When a famous shipment of tea was jettisoned in Boston harbor in 1776, with far-reaching consequences, the work was done by hand. To-day modern freight handling machinery and efficient harbor control of machinery is indispensable. The development of the railroads worked a transformation. Many new elements enter into the problem of attracting freight and commerce. The West must be drawn upon to develop a great eastern seaport and New York profited more than Boston by this commerce.

The recent development of Boston harbor will capitalize her great natural advantages and make a strong bid for a larger share of the Atlantic shipping. The harbor has been adequately warehoused. One of the largest and best equipped piers in the country, the Commonwealth pier, has been completed. The port has an excellent arrangement of railroad tracks, grain elevators and freight-handling machinery. With this equipment, it is expected that the next few years will bring a remarkable development and the old preëminence may return. The great modern harbor at Boston dates from 1902, when work was commenced on channels, thirty-five feet in depth, which opened her harbor to the great ships of the world. At present Boston is second only to New York in exporting cattle and dairy products and contains the largest wool and fish markets in the world, with the single exception of London.

The growth of the port of Philadelphia in the face of obvious handicaps illustrates an interesting phase of harbor development. The city lies far inland, necessitating a long trip of 110 miles to reach the sea. It is therefore less fortunately placed than Boston, New York, Baltimore or Charleston, yet has held a large share of commerce throughout its history. This is largely due to the fact that Philadelphia is a great industrial center and is well served by railroads. The harbor again profits by the erection of modern piers and pier machinery which are models of their kind.

Profiting by the experience of New York and other cities the new Philadelphia piers have been built with an unusual width of 300 feet. The congestion of most American piers is due, of course, to their narrowness. The Philadelphia piers have two separate sheds. The roomy transit-shed floors are placed on each side of a central track. A driveway for teams runs down the center of the pier, while the car tracks are moved to the outer edge. This arrangement makes it possible to load from ships on both sides of the pier at the same time and transfer the freight to trains or trucks without crossing traffic and consequent congestion.

Extraordinary measures have been taken to guard the entrance to the Delaware River, leading to Philadelphia, for the protection of shipping. At the southeast extremity of Delaware Bay a great artificial shelter has been provided by building two breakwaters about a quarter of a mile apart. The first of these is 2,556 feet in length and the second, the ice breakwater, is 1,359 feet long. The work here was commenced as early as 1829. For many years it has been the principal harbor of refuge along the entire length of the Atlantic coast.

A striking example of the influence of the World War on American ports is afforded by Baltimore. Her position near the sea has lent her a great advantage and her intercoastal trade has been very large for a long period. At the opening of the war trans-ocean liners sailed from Baltimore to twelve or fifteen foreign ports. To-day Baltimore harbor has forty-three steamship lines with fifty-five services, which sail regularly to more than one hundred foreign terminals.

Baltimore has an excellent harbor divided into three parts. It is entered at Fort McHenry by a channel 600 feet in width and thirty-one feet deep. The harbor penetrates far into the city, accommodating vessels of the largest type which thus can load and unload conveniently to the distributing centers.

To provide adequate facilities for this rapidly expanding trade, $50,000,000 is to be expended in port development. Facilities are provided for handling all types of cargoes. Baltimore at present is the sixth port in the United States as regards the tonnage of its foreign and domestic fleets. The geographical position of Baltimore and Norfolk is obviously very favorable for development as great world ports. Both are readily accessible from the sea throughout the year, and have excellent natural harbors which have been intelligently developed. Both stand on great natural waterways draining an immensely rich country and which carry a valuable water-borne commerce to their very doors.

The finest natural harbor on the Atlantic seaboard, except New York, is doubtless that of Charleston. It also has the great advantage of being but seven miles from the sea, while New York lies more than seventeen miles inland. The form of the harbor suggests that of New York, since the city occupies a narrow peninsula bounded by two rivers and extending into a bay, much as does Manhattan Island. An interesting problem has been solved here in assuring a free entrance from the sea past several sand bars at all times, by guarding the channel with artificial boundaries.

Charleston is generally considered the finest jetty harbor in the world. It stands at the mouth of a large natural tidal basin some fifteen miles square. Left to itself the sea piled up a dangerous sand bar less than two miles out, extending for ten miles southward. There were half a dozen channels to the sea, but these shifted from time to time and proved extremely baffling to navigators. The problem was solved by building great jetties to improve the depth of the channel across the bar. The jetties start out from the shore two and a quarter miles apart and converge to a width of 1,900 feet just over the bar. The mysterious currents of the sea which formed the bar were successfully outwitted and a safe entrance is assured throughout the year.

CHAPTER VI

THE PORT OF NEW YORK

MEASURED by its commerce, its natural advantages and possibilities of development, New York harbor occupies a unique position. The shore line of the natural harbor is more than 776 miles in length. It handles a foreign commerce greater than that of all other seaports of the United States on the Atlantic, Pacific and Gulf of Mexico. An ocean liner passes in or out of the harbor on the average, every ten minutes throughout the day, carrying the house flags of some one of 200 steamship lines. Within a radius of twenty-five miles of the Statue of Liberty, which looks down upon the upper harbor, may be found a population of over 8,000,000. The value of manufacturing industries directly in touch with these waters exceeds the combined industries of the four next largest cities of the country, Chicago, Philadelphia, Detroit and St. Louis. To supply the metropolitan district for a single day, a train of freight cars would be required ninety miles in length. Twelve railroads bring to New York every year freight for domestic use or export which would fill a line of cars reaching around the world.

The harbor which makes possible this commercial and industrial activity has wonderful natural advantages with corresponding limitations. On approaching New York from the sea a vessel may take advantage of a spacious shelter harbor formed by a long protecting cape, known the world over as Sandy Hook. The broad Lower Bay of the harbor beyond this point has an area of eighty-eight square miles. The broad bay, once filled with dangerous sand bars, is now traversed by many channels. The deepest of these, the Ambrose Channel, with a width of from 950 to 1600 feet, has a depth of forty feet at all tides in every season and accommodates the largest ships in the world.

A great extension of New York harbor is contemplated in this region opening directly upon the sea. It is planned to develop the natural harbor known as Jamaica Bay which is traversed by shallow channels dotted with many islands. This vast area is to be dredged and filled, affording unlimited space for factories and industrial plants, which may be reached by deep water channels. The harbor will have the advantage of being seventeen miles nearer the sea than Manhattan, and will eventually profit by railroad connections with the mainland.

The Upper Bay is guarded by the Narrows, a natural gateway less than one mile in width, dominated on either side by low protecting hills. A great inner harbor, fourteen square miles in area, extends from this entrance northward to Manhattan Island. Here the waters are divided into two great streams, the Hudson and the East Rivers, each nearly a mile in width, extending northward. The main docking facilities are to be found in the upper harbor, on the shores of Manhattan Island and the opposite shores of the rivers.

This unique geographical arrangement has been largely responsible for building up the largest and richest city in the world. The great harbor, so accessible from the sea the year round, offers ample protection for shipping. The vessels engaged in domestic or foreign trade dock at the foot of the busiest streets of New York. The traveler bound for London, Paris or Berlin on reaching Europe finds himself on landing several hours distant by train from his destination. The freight from abroad must be laboriously loaded from ships to trains to be hauled a considerable distance, when it must again be carried by truck to its ultimate destination in stores or factories.

The passenger from a trans-Atlantic liner on reaching New York finds himself at the very door of the retail, wholesale or manufacturing centers. Incoming freight, measured by millions of tons, is transferred by a single haul direct from the steamer to the distributors. The amazing development of

Manhattan Island has followed as a matter of course.

The growth of New York harbor is probably without precedent. In 1791 the total tonnage of all the ships passing in and out of the port was less than 5,000. In the following year the commerce suddenly jumped to ten times this figure. The next half century brought an amazing development. The impetus was given nearly a century ago by the opening of the Erie Canal, thus establishing a waterway from the Great Lakes to the Atlantic. New York has also enjoyed advantages due to the convergence of many railroads. Just before the Civil War the total tonnage per year had risen to about 1,000,000. During the World War the tonnage of all vessels passing in and out of New York harbor reached annually the amazing total of over 2,000,000,000.

The great fleets of ships engaged in foreign and domestic trade find the harbor for the most part well suited to their convenience. A sail of two hours or less from the sea brings them to the great systems of docks in many parts of the harbor which are well placed and designed for transhipping to railroads reaching all parts of the country, while cargoes may be received directly from trains brought to the docks. Many of the great manufacturing plants of New York are readily accessible from the harbor, and can receive cargoes of raw materials and ship finished products with a minimum of expense.

Measured by tons, coal is by far the most important commodity handled in New York harbor. Of 76,000,000 tons of freight brought to the port district by rail in a year, 38,000,000 tons is coal. It may help to visualize this vast coal pile to remember that were it loaded in forty-five-ton cars a train consisting of 850,000 coal cars would be required to carry it. The machinery employed for handling this immense coal traffic is highly efficient.

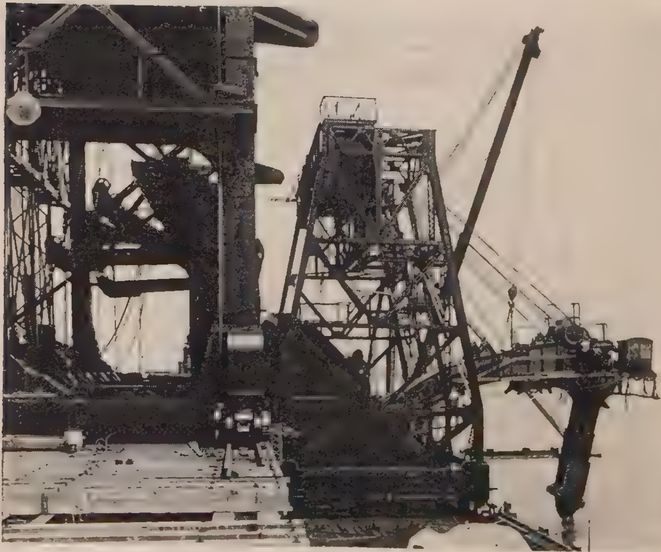
The coal must be loaded aboard ships of many kinds. In loading coal, powerful coal dumpers are employed which do the work of many thousand pairs of hands in a few seconds. The combined daily facilities of these coal terminals is 3,200 cars or 144,000 tons of coal. During the process each car may be weighed before and after dumping. Thoughout New York harbor the coal barge is always in evidence. More than 8,000 vessels clear from New York every year, one half of which are in foreign trade. To coal this immense fleet 6,000,000 tons must be regularly bunkered. Fully ninety per cent. of the bunker coal is brought alongside ships in barges and raised by various derrick devices and deposited in the ships' holds.

It is interesting to note in this connection that freight carrying ships visiting New York harbor remain in port as a rule from twelve to forty days. The river and sound steamers which carry freight through inland waters remain at their docks from one to five days. The great trans-Atlantic liners remain at their docks as a rule on the average from five to six days. The longest visits are made by the tramp steamers, especially those coming from a distance. The average

Photo by Irving Underhill

A TYPICAL SCENE IN NEW YORK HARBOR

LOADING RAILROAD TRAINS AFLOAT



MODERN DOCK EQUIPMENT FOR TRANSHIPPING CARGOES time spent in port by freight-carrying craft, exclusive of domestic and coastwise trade, is nineteen days.

Under the present plan a large part of the traffic brought in by rail is "broken up" on the western or New Jersey side of the Hudson River. An immensely complicated transfer system has been developed to handle this freight. It is transferred to private sidings, local stations, waterfront piers, elevators, etc. These millions of tons of freight are carried across the river by being transferred to lighters and ferried to some dock, perhaps in a far distant part of the harbor. There is obviously an immense amount of lost motion in this system.

The broad waters of the harbor are, in a sense, therefore, bridged by an elaborate system of lighters for transporting many forms of freight, and by fleets of car floats which annually ferry thousands of miles of railroad trains. The lighterage service has been described in detail in another chapter. The car floats which transfer "unbroken" freight are usually equipped with two tracks running from end to end, although some floats carry three tracks. A covered runway often extends from end to end of the float at the center with the platform on a level with the doors of the freight cars. It is thus possible to transfer freight from one car to another across this platform.

The method of handling such freight is clearly illustrated in the photograph reproduced facing page 113. When the picture was taken the openings on the dock were on a line with the open doors of cars on three lines of tracks upon one of the floats. It is thus possible to look directly through three freight cars. A very busy scene has been caught which gives an excellent idea of the method of working cargo under these unusual conditions.

The car float is employed in many American harbors. The freight car used on American railroads is much larger than those of European countries and makes it possible to handle great volumes of freight much more efficiently than under the European system. On the Great Lakes the car floats carrying trains of passengers as well as freight or coal cars make long journeys by water. They are often equipped with radio to keep them in touch with land. A float carrying sleeping and dining cars thus becomes practically a floating hotel and offers the same conveniences and luxuries which would be enjoyed on a steamboat.

New York faces a serious problem. The geography of the vast harbor presents many obvious difficulties. Her enormous commerce has been attracted in the past without especial effort. To her great harbors has flowed the commerce of the world. If New York is to maintain her preëminent position as a world port, despite the rivalry of other harbors of the Atlantic, she must quickly find a solution for its complicated port problems. The natural advantages of the harbor are unrivaled. Its great size and the breadth of its waterways at the same time present an element of weakness. The problem, in a word, is to unify the great harbor, and set up cheap and rapid systems of communication between its furthermost boundaries.

Although New York's position as the first port in America and the world is scarcely threatened, certainly not in this generation, the competition of several rival ports is steadily making itself felt. New York has already lost much of her grain trade to Montreal. A large part of her commerce in cotton and tobacco has been drawn from her by other ports. The opening of a great ship canal by way of the St. Lawrence would divert an immense volume of shipping. As the waterborne traffic down the Mississippi River increases New York will suffer a certain loss. The Panama Canal has diverted much shipping from Atlantic ports. The improvement of many great harbors along the Atlantic seaboard will serve to attract commerce which in the past has sought New York.

To meet this rivalry New York must provide better facilities. More room must be found for all varieties of shipping. The docking facilities must be increased to do away with costly delays. The machinery for loading and unloading every type of craft must be improved to reduce the cost of transhipment. Probably the most urgent problem is to devise cheaper and more efficient methods of transporting cargoes of every form across the broad harbor. Upon New York's ability to solve these problems may largely depend her supremacy in the future.

The Hudson River, bounding New York on the west and separating Manhattan Island from the mainland, is a serious barrier for the enormous traffic which must pass between the island and the mainland. Today some eighty per cent. of the enormous rail tonnage reaches the harbor on the mainland or New Jersey side. On the other hand seventy-five per cent. of the shipping of New York is handled wholly from the New York side of the harbor. The problem of transporting this immense volume of freight across the broad rivers and through the already highly congested streets of Manhattan Island, the busiest and most crowded section of the city, is without parallel. Meanwhile the volume of freight is rapidly mounting and the harbor is becoming more and more congested.

Despite the enormous sums which have been spent on improving New York harbor this tonnage must still be floated in primitive fashion from shore to shore. The lighterage ferry and railroad float system employed to do the work is the most complete of its kind in the world, but it is nevertheless crude and inefficient. In planning improvements there are two general schemes for solving this vexing problem, to tunnel or to bridge the river. The best engineering talent in the country has been engaged to solve the problem. One group of engineers advised that relief can only be found in the construction of a giant bridge to carry both railroad and vehicular traffic across the river. The structure would be by far the largest bridge in the world. The towers required for a suspension bridge at this point, it has been calculated, would be higher than the highest skyscraper in the world and the completed structure would cost well over $100,000,000.

Another group of engineers believe that the solution of the problem lies in tunneling the river and bay. There are at present four tunnels beneath the Hudson River, carrying an enormous passenger traffic. A great vehicular tunnel is now being built which will accommodate 3800 cars in an hour. It is urged that a number of tunnels may be built for the cost of a single bridge, and that they can be built in much less time.

Work is well advanced, meanwhile, on a great railroad tunnel beneath the Narrows which separate Staten Island from Long Island at the entrance to the harbor. Shafts have been dug at either end of the tunnel to a depth of ninety feet. The double tunnel which will pass beneath the Narrows will be about two miles long between these shafts. This will make it possible for several railroad lines from the South and West to run trains directly into Brooklyn and eventually to New England. It is planned to build a passenger station in Brooklyn where trains may be taken to Washington or Chicago without change. An enormous volume of freight, it is believed, will thus pass from the mainland to Long Island on the opposite side of Manhattan, relieving the congestion which now exists and developing great new industrial centers.

The Port of New York Authority has planned a complete system of belt-line railroads, connecting lines to link up the existing systems, with many tunnels throughout the port which will make possible cheap and rapid intercommunication between all parts of the harbor. The estimated cost of this development is $400,000,000. It is proposed to make each of these improvements pay for itself by the economy of transportation it will make possible.

The Port Authority further plans to solve the river problem by building a great modern freight receiving station on the western side of the harbor where freight will be "broken up." This is to be connected with Manhattan by a series of freight subways, running through tunnels beneath the mile-wide river and under the streets of Manhattan.

At a score or more of points special underground freight stations will be built extending down to the level of the freight subway. Trucks will be lifted from the street level on ramps or inclines to the level of the tracks. A system of powerful elevators may carry the freight cars to the upper levels. Great factories or office buildings will be built above the underground stations.

It is planned further to extend the system of underground freight railways throughout the busy section of New York. At present some 30,000,000 carloads of freight annually pass through the busiest city in the world. By handling this immense traffic below the surface the cost of transportation will be greatly reduced. A ship's cargo can thus be unloaded and transferred quickly and cheaply by modern docking machinery to cars which will be run through the freight tubes beneath the harbor to any part of the city.

It is pointed out by some of the leading engineers of New York that the present system of lightering an immense tonnage of freight across the broad rivers which surround Manhattan Island is an antiquated method, and that if the city is to compete successfully with other modern seaports, a more efficient system must be devised and installed without delay. New York harbor has been compared to the hare which, confident of its speed, lay down to sleep. The tortoise, in this case typified by rival ports, meanwhile is rapidly overtaking New York, and may some day pass her, gaining and holding an important part of her foreign shipping.

CHAPTER VII

LOOKING DOWN ON NEW YORK HARBOR

FROM the top of one of the great skyscrapers on lower Manhattan Island it is possible to look directly upon a vast expanse of New York harbor and its innumerable activities. The outlines of the great waterways are sharply etched as far as the eye can see. At any hour of the day one can count a hundred or more craft afloat, and many hundred more at the docks which border the channels. A marvelous panorama is unrolled which is constantly changing before one's eyes. Watch this animated picture for an hour and the activities of the harbor gain an entirely new significance. It is probably the most fascinating lesson in geography in the world.

An excellent vantage point for studying this movement may be found in the office of the Port of New York Authority atop a great skyscraper near the foot of Broadway. These offices on the topmost floor open on three sides, the east, south and west, thus looking directly down upon the busiest section of the great harbor. Here will be found, incidentally, a group of engineers widely recognized as experts upon every phase of the problem of harbor development. The complicated movement of the harbor is in progress at one's feet, and as these experts analyze it they will illustrate every phase by pointing directly to its actual operation.

The secret of New York's rise to power as a great world port is revealed at a glance. Manhattan Island lies directly below, its boundaries drawn by a continuous series of long docks extending out into the rivers. Here lie crowded together an enormous fleet drawn from all parts of the world. Since a vessel bound to or from some foreign port passes in or out of the Narrows at the entrance to New York harbor on the average once in every few minutes, carrying a bewildering assortment of freight and passengers, it is easy to understand that the narrow island at one's feet has become a great clearing house for the world's commerce.

South of Manhattan Island the two great rivers join and spread out into a broad bay, bounded by miles of docks and dotted with innumerable craft. If the day be clear the Narrows may be seen in the distance and beyond it the outer harbor and the open sea. With the broad rivers on either side of the island there are over 115 square miles of deep water in which great vessels may lie in perfect security. More than one half the total foreign trade of the United States passes through the harbor, it will be seen, without visibly crowding it.

To the north the broad rivers bounding Manhattan Island stretch away as far as the eye can see, each lined with continuous rows of piers. The piers are surprisingly uniform. All are built exactly at right angles to the shore line, and extend out into the rivers on an average of 800 feet, with just enough space between them to accommodate a ship on either side. Obviously it is a snug fit and the ships must be skilfully manœuvered to enter.

Watch the great panorama more closely and the complicated system of handling this immense volume of commerce is revealed. The broad expanse of water below one is never free of craft in bewildering variety. The most interesting of these craft are of course the ocean liners. The great bulk of the 900-foot ships of 50,000 tons burden renders them visible many miles down the harbor, and from these windows they can be watched without interruption as they move majestically to their docks. Arriving at their piers they will turn slowly at right angles to the river, almost spanning the broad stream, when they will cautiously nose their way in between the piers and make fast. The operation of docking, known as "warping in," is a very familiar sight in New York harbor. When a great liner is warped in, hours may be required for the operation with a fleet of a score of tugs assisting.

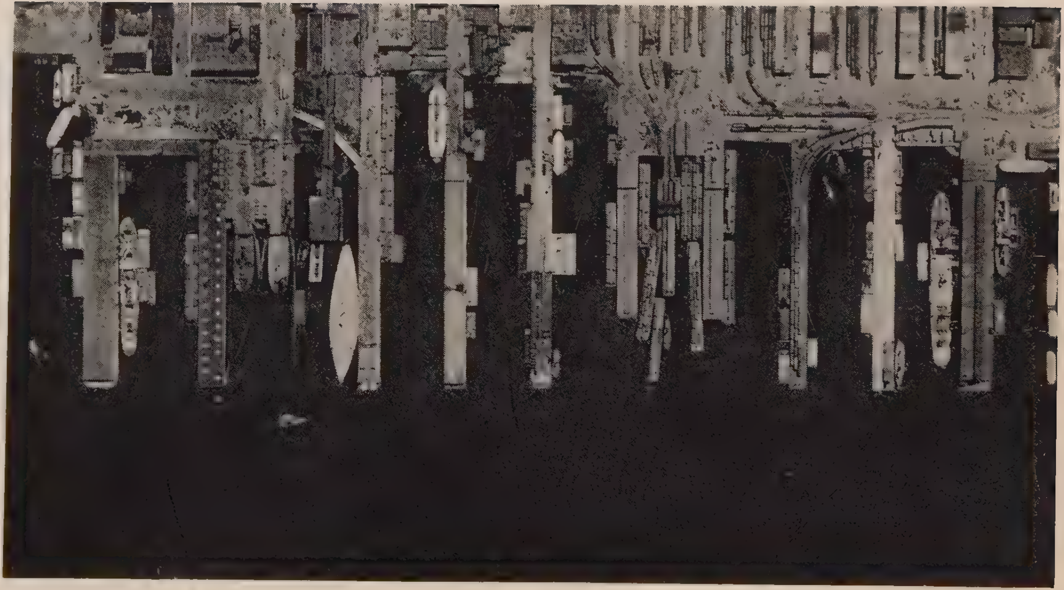
After the steamers are made fast, you will see great fleets of taxicabs and other vehicles leaving the shore end of the steamer docks. Later long lines of trucks will depart loaded with freight from the incoming steamer. Here is a remarkable illustration of the passenger and freight movement of New York harbor. Let the steamer dock, and the customs officials be satisfied, and the passengers are in their business offices or homes in a few minutes. The thousands of tons of freight the steamers carry may be transferred directly from the steamship dock to their destination.

From this vantage point at the crest of New York's skyline one seems to look directly down on the broad streets bordering the river. Throughout the day the streets seem to be choked with traffic, despite their width. New York lacks a belt line connecting its river piers, such as have been built in most modern terminals. These broad streets in a measure serve the same purpose. The movement of freight is much slower when carried by motor truck or horse-drawn vehicle, and far more expensive, but has some compensating advantages in being extremely elastic.

As one looks down from this height innumerable moving vehicles of toy-like dimensions may be seen weaving back and forth in and out along these broad streets as far as the eye can see. The broad streets also serve as open warehouses throughout many hours of the day. The enormous volume of freight which must be carted to and from these piers throughout the city overflows the great sheds and must be piled in the street in all sorts of weather. A typical West Street scene is shown in the photograph reproduced facing page 128.

Look more closely with the aid of a glass and you will see that by far the greater number of these are horse-drawn. It is literally true that the horse has come back, and is replacing in large measure the auto truck in handling this freight. A recent census shows that seventy-two per cent. of all these vehicles are horse-drawn, as compared with twenty-five per cent. of gasoline-propelled

A NEW YORK DOCK STREET WITH ITS OVERFLOW OF FREIGHT



AIR VIEW SHOWING INTENSIVE DEVELOPMENT OF NEW YORK DOCKS vehicles, while a trifling number are electrically driven. This curious situation is explained by the fact that the movement of street traffic near the docks in New York is so slow that the horse proves cheaper than the automobile. The congestion is so great that delays of many hours are inevitable. A horse-drawn vehicle standing thus becalmed represents much less loss than the gas-driven truck.

Meanwhile the waters about the piers have been quickly crowded with a variety of craft to assist in unloading and reloading the liner. The first to arrive will probably be a variety of covered barges and several forms of lighters for carrying off the incoming cargo. The liner is equipped with steam or electric derricks which will raise the cargo from the deep holds and swing it outboard and lower it directly on the waiting boats. These in turn will scatter to all parts of the harbor. Later broad scows loaded with coal will be brought alongside to refuel the great liner, while other fleets of lighters and barges will be drawn alongside to transfer their cargoes to the holds of the outgoing steamer. These liners ply back and forth across the Atlantic on a definite time table, like so many railroad trains, remaining only a few days in port, and no time may be lost in transhipping their cargoes.

One of the most picturesque craft visible in the harbor is the railroad float with its trains of cars. Looking down from the sky-scraper on lower Manhattan Island there is not an hour in the day but several of such trains may be seen. In other words there are usually many miles of railroad trains afloat in the harbor.

The floating freight train helps to visualize another important phase of the harbor activities. On the New Jersey and mainland shore a mile away one can see several great railroad terminals where the freight from the West must be halted. Nine railroad lines every year discharge millions of tons of freight on this shore which must be carried across the river. Much of this freight is carried over in the same cars which have brought it from distant points to the west and south. Once loaded, the trains are floated directly to the pier stations in other parts of the harbor, where they are unloaded and reloaded without removing them from the tracks of the float. From these pier stations the freight may be carried by trucks to their destination.

Again the trains are often run on tracks at the water's edge and hauled to yards specially equipped with machinery for unloading freight. Another plan is to unload the innumerable cars directly into lighters which are floated to all parts of the harbor. This endless transfer of freight lends the harbor an animated appearance.

The lighter in New York harbor takes on a hundred different forms. It is everywhere in evidence at all hours of the day. The simplest lighter is a mere open boat or yaul; the largest of them a complicated, steam-driven craft with enclosed decks and power-derricks. Any craft which cannot be otherwide classified in the panorama below may pretty safely be called a ship's lighter. They are clustered about the dock of every incoming or outgoing steamer and like innumerable shuttles constantly moving back and forth across the broad harbor.

A tug boat of some form may be called almost as quickly in New York harbor as a taxicab in the city streets. Let a ship in any part of the harbor sound the whistle demanding the services of a tug boat, and the waters in every direction will soon become alive with craft hurrying to the call. At any hour of the day scores of tug boats may be summoned in this way in a few minutes. Let a distress signal be sounded, a marine fire alarm for instance, and hundreds of such craft will be in sight in an incredibly short time.

The eye is soon puzzled by many unfamiliar craft. To carry on the immensely diversified activities of New York harbor, a bewildering variety of craft is constantly required. The giant steam dredges, a nondescript looking craft, are a familiar sight. They are often very bulky, with two or more enclosed decks, and may be identified by their powerful scoops and other dredging devices. They may be seen anchored in various parts of the harbor, often in mid-channel hard at work, with several open scows fastened alongside to receive the sand and rock laboriously dug from the harbor bed.

One of the most picturesque craft is the topheavy towering elevator frequently seen as it is towed about the harbor or in position alongside an ocean liner. The cabins which house the complicated elevating machinery are shaped like huge cones or rather square prisms, rising as high as the smokestacks of the steamers. A sudden squall of wind and one would expect to see them topple over. They usually make very slow headway against the tide and winds and are perhaps the slowest moving craft in the harbor. Once set to work, the nimble machinery in this attenuated cabin will perform prodigies of work. Probably no single craft confined to local waters plays so essential a part in keeping the great commerce of the harbor in motion.

The waters again are rarely free from long tows of canal boats in their deliberate progress up and down the harbor. As many as fifty laden boats may be combined in a single tow. They have probably been loaded in the Great Lakes or far to the north or east, and are now nearing their destination. Such a tow, each unit carrying a family, forms a floating town of several hundred inhabitants. They will come to port at the great canal boat terminals where their freight will be transhipped to harbor craft, for distribution in local waters, to the railroad docks or to outgoing steamers.

The most elaborate of these craft are the oil tankers which seems to be constantly in evidence. Loaded they appear to be low lying canal boats with their decks almost awash. Freed of their cargoes they rise from the water, revealing hulls like those of ocean liners. The largest of the oil tankers are in reality great ocean steamers, moving under their own power. The tankers must not be confused, however, with the bulky coal barges which carry great stores of coal up and down the coast and which, like the oil craft, rise out of the water when empty, revealing surprising underbodies.

The marine fire-fighting craft of New York harbor is famous. At the foot of Manhattan Island almost directly below the offices of the Port Authority stands a fire station with several tugs equipped with fire-fighting apparatus with steam up ready to respond to a call at an instant's notice. A number of such stations are scattered throughout the harbor and in case of fire the craft may be brought into action in a few minutes. If the fire be serious a dozen such boats will be quickly assembled, each directing powerful streams of water from every angle upon the burning craft or docks. The fire tugs usually travel at forced draught and their speed quickly attracts the attention of an experienced eye.

To safeguard the great fleets in these waters, New York harbor is equipped with the most complete salvaging machinery of any port in the world. Let a call of distress be picked up by radio at any hour of the day or night, announcing a disabled ship or wreck anywhere in New York harbor or along the sea coast for hundreds of miles, and these craft may be dispatched in a few minutes. The wrecking craft carries complete and powerful machinery of every kind for aiding craft in distress, and experienced crews of workers. The reward for salvaging ships is large and no trouble or expense is spared in keeping these emergency craft ready for action.

The busy harbor beneath our eyes has complicated traffic problems. The channels often become congested with shipping, exactly as a city street is overcrowded with vehicles. A great many ships cannot find space at the docks and must anchor off shore and it becomes necessary to enforce definite traffic regulations. An elaborate system of marine policing has been worked out for New York harbor which has proved invaluable in safeguarding every form of craft.

The duties of the marine traffic cops are more complicated than the landsman imagines. The great channel about the harbor must first of all be guarded by keeping the ships moving and by warning them should they be off their courses. This work is done for the most part by the system of signals placed throughout the harbor which shine from lighthouses and floating buoys. The harbor regulations are of course familiar to the navigating officers aboard all manner of craft. A foreign vessel entering port takes on a harbor pilot so that the thousands of craft passing in and out of New York rarely transgress the traffic regulations.

The harbor police are kept busy day and night, however, in patrolling the ship anchorages. These areas are definitely indicated on the harbor maps, with the channels which lead to them, and the traffic regulations governing all ships using these anchorages are enforced as rigidly as on a crowded city street. A vessel is assigned to a position in one of these anchorages. Although the anchorages are many miles in length they are frequently crowded.

The exact position at which each vessel must drop anchor is determined by making observation from fixed points ashore. The anchor chain acts as a tether allowing the vessel to swing about to the tide through a great circle, with a diameter equal to about twice the length of the ship, plus the anchor chain. Unless the ship anchors exactly in the position assigned to it there is obviously danger of collision when the tides turn. If through any carelessness in anchoring such a collision occurs serious loss may follow.

The traffic police have their hands full in patrolling the anchorages occupied by foreign vessels. The officers in charge may not speak English or be familiar with the traffic rules of the harbor, and the orders must be given by signs. If a vessel be found off the anchorage assigned to it, it is obliged to change its position at once. It is only by strict enforcement of the letter of the law that the vessels in the anchorages are protected from each other, and harbor channels kept clear day and night for the regular movement of harbor traffic. The penalties for neglect of these rules are severe.

The traffic police must also regulate the movement of explosives through the harbor. Special anchorages are set aside for vessels carrying dangerous cargoes. They are obliged to fly a red flag to announce their approach. As a rule other vessels in passing them give the craft with the red flags a wide berth.

During the World War when New York harbor was crowded to capacity there were hundreds of vessels forced through lack of docking facilities to occupy these anchorages. For many miles the regular ship channels were lined continuously with vessels. A single mistake in fixing these anchorages or forcing the great fleet to obey the harbor traffic rules might have caused a serious accident, but the great fleets of ships inward and outward bound threaded their way for months through this congested traffic without a mishap.

A severe test of the efficiency of the harbor patrol is frequently afforded when one of the great naval fleets visits a crowded harbor. It frequently happens that 200 or more war craft will thus enter a port already overtaxed with shipping. The plans for the visiting fleet are worked out in detail in advance, and a definite anchorage is assigned to every craft from the superdreadnaught to the smallest naval tug. A fleet comprising 272 war craft once visited New York harbor and remained for several weeks. The war craft passed and repassed through the crowded ship lanes and occupied their anchorages bordering the busy river channels without the slightest mishap.

A unique opportunity for visualizing harbor problems is afforded by the aëroplane. It makes it possible to look directly down upon the complicated grouping of ships in all parts of the harbor, much the same as from the New York skyscrapers. These photographs, taken from aloft, visualize in detail the problem of dock design like a mechanical drawing, but at the same time seem very much alive. Two aërial views are reproduced on other pages which have caught, by a lucky chance, characteristic scenes of the complicated shipping problem of New York's harbor.

Most trans-Atlantic travelers are familiar with the Chelsea docks at New York which are the points of departure and arrival of most of the great liners. Travelers will retain vivid mental pictures of broad streets, crowded docks and busy decks, with a glimpse of the river front of the docks from mid-stream. One may have visited these docks a hundred times, yet the aërial view, by throwing into vivid contrast all the details of this great group of docks, will come as a surprise.

The remarkable aëro view reproduced as a frontispiece has caught one of the busiest scenes in New York harbor. The docks here shown are the longest in the harbor, reaching out into the Hudson River for 900 feet. They were especially extended to this length to accommodate the largest ocean liners in the world, which dock at this point. An excellent illustration is thus afforded of the method of building piers in New York waters. A bulkhead of masonry bounds the ends of the city streets. From this the docks are built out, it will be seen, at right angles.

The docks used by the 900-foot liners on the other side of the Atlantic are so arranged that the vessels can come alongside without warping in. The photograph illustrates at a glance the difficulties of docking vessels of such size in New York. It frequently happens that twenty or more tugs are required to turn one of these ships and an hour or more is consumed before the vessel is placed safely parallel to its pier and made fast.

The aërial view is characteristic of New York harbor since it shows every dock occupied. In this comparatively limited area, the photograph has caught not less than eight ocean liners. The largest of these is the famous *Olympic,* easily recognized by her four smoke stacks. The liner, which appears a mere toy in the picture, measures 852 feet in length, has a tonnage of 46,439 and is the fourth largest vessel afloat. The rest of the fleet is dwarfed by this giant, although the smallest of the other liners seen apart would be impressive.

The advantage of this system of docking, which is common to most American harbors, is obvious. The steamers lie broadside to the long piers and can be loaded or unloaded from all their hatches at the same time. The cargo is transferred by means of cranes carried by the ships. There are no dock cranes for working on these piers. The cargoes are transferred directly to the docks and carried away by horse- or motor-drawn vehicles which have direct access from the street. The piers in this case are double decked. The lower decks are used for freight and the upper decks for passengers. The two decks are connected by both freight and passenger elevators.

The steamers it will be seen are surrounded by fleets of harbor craft used for transferring cargoes. There are several types of lighters in position alongside. Among these will be seen the covered barges so much used in New York harbor. These are easily loaded or unloaded and the housing affords protection for a large volume of cargo. Several of the lighters carry their own derricks. A number of coal barges are naturally in evidence, for the operation of coaling is almost continuously in progress while the liners are in port.

An excellent illustration is here afforded of the common practice of "broaching off." The ocean steamer in this case has been moved out from her pier far enough to allow several coal barges and lighters to come between her and the dock. This makes it possible for the cargo to be worked from both sides of the ship at the same time, so that the work may be done in about half the time ordinarily required. All of the deck openings and side ports can thus be brought into play at once.

Since these ocean liners are the largest transportation units in the world a great loss follows every hour's delay in working cargoes. They must sail upon a fixed schedule like so many railroad trains, and as a rule they remain for only about a week in port. It is absolutely essential therefore that their cargoes be removed and new outgoing cargoes stowed away in their vast hulls, and their bunkers be replenished, within the limited time they are allowed to remain in port.

It is difficult to realize how great an investment is represented by this diminutive group of toy-like boats. The smallest of these craft cost several millions of dollars. The crews of the largest liners total upwards of 2,000 people. Several thousand more are employed on the docks and aboard the harbor craft necessary for handling their cargoes. Every minute therefore counts in unloading these craft and preparing them for the sea.

Another characteristic scene on New York's crowded waterfront has been caught by the aërial camera in the photograph reproduced facing page 129. Any one familiar with New York will recognize the docks which jut out into the Hudson River in the general vicinity of West Forty-second Street. At the extreme right of the picture this familiar crosstown street is bounded by a double ferry slip. The picture, it will be seen, was snapped from a considerable altitude, for the ferry boats appear very small. The white ship to the right of the ferry boats is the *Hendrik Hudson,* one of the largest river steamers afloat.

The piers in this region, clearly, are very long, thus affording docking space for a number of vessels of all types. They are unloaded or loaded directly from the docks, reached by horse-drawn and motor trucks. The harbor lighters are brought between these piers and tranship directly to the ships at the docks. In this part of the harbor canal boats, which have made the entire trip from the Great Lakes or other inland waters, may be brought alongside the seagoing vessels for transferring cargoes.

The most interesting feature of this section of the water front is doubtless the railroad connections with the floating railroad barges. The fine tracery of parallel lines to the right of the picture form a great railroad terminus. Trace the tiny tracks and you will notice that they appear to run far out into the piers. The outer tracks are laid upon float bridges. The trains are run directly upon them. Look closely and it will be noticed that several of these car floats laden with trains of freight cars are lying in the pier while several of them are detached from their docks and afloat.

CHAPTER VIII

RISE OF THE PACIFIC PORTS

WESTWARD the movement of the world's commerce inevitably takes its course. The growth of the Pacific coast ports is unique in the long history of trade. Less than a century ago a vessel was a curiosity on this interminable coast line. When Richard Henry Dana made his memorable voyage to the Pacific he cruised along the coast of California for months without sighting a craft of any kind, and found the harbor of San Francisco without a single sail. To-day more than $1,000,000,000 worth of foreign trade passes each year through the harbors of the Pacific, and half a dozen great ports are being developed on unprecedented lines to handle the shipping of the immediate future. The wealth of the Indies was the great lodestone which called mariners to venture upon unknown seas, and incidentally to discover America. The ports on our west coast, which are bidding to-day for the Eastern trade, occupy a highly valuable strategic position, and profit by several centuries of experience in attacking this ancient problem.

Along the Western coast may be found some of the finest natural harbors in the world, notably at San Francisco, Seattle and Tacoma. The work accomplished at Los Angeles in building a great artificial port is probably without parallel. All these ports handle the products of an immensely rich hinterland. During the World War an unprecedented volume of commerce was diverted to these ports, which awakened them to the possibilities of their positions. In 1918 Seattle was for a year the second port in respect to tonnage in the United States. The plans for harbor development along the coast, contemplating an expenditure of hundreds of millions of dollars, are convincing proof that the entire Pacific coast is thoroughly alive to the possibilities of the future.

The great natural harbor of San Francisco permits an unlimited development, nor are there lacking engineers with vision in planning its future. By a curious chance the harbor of San Francisco enjoys the same advantages, and it suffers from the same limitations, as that of New York. Both are convenient to the sea and their waters are landlocked and spacious. In each case, however, the principal railroad terminus is on one side of the harbor, and the central business sections and the mass of the population on the other. The broad waters of both harbors, which prove so invaluable for shipping, at the same time form serious transportation barriers.

As the natural advantages of New York harbor have served to develop the greatest port of the Atlantic, so the great natural harbor of San Francisco attracts a large share of the commerce of the Pacific. Along the entire Pacific seaboard it is the only harbor which rivals, if it does not surpass, the great natural advantages of Puget Sound. Lying nearer the sea than New York or Seattle, San Francisco has a marvelous opportunity for building up a great unified port terminal.

San Francisco is attacking its port problems on a different plan than New York. Fortunately the entire waterfront, from the famous Golden Gate at the entrance to San Francisco Bay to the boundary of the adjoining county, is owned and controlled by the State, which makes it possible to carry out a harmonious scheme of development. A great sea-wall, some 20,000 feet long, parallels the waterfront of San Francisco and from this extend out at right angles into the bay scores of piers of various dimensions, affording a berthing space of 50,000 feet. Back of the sea-wall and paralleling the harbor is a spacious waterfront street 200 feet in width. So far the port problem has been solved in much the same manner as on Manhattan Island.

The movement of freight around the harbor is greatly facilitated by a terminal belt line with some fifty miles of track which serves practically all the piers. The development represents an investment of $50,000,000. New York has long suffered from the lack of a belt line. A great terminal warehouse, designed on modern lines, has been erected at San Francisco at a cost of $2,000,000. Many new piers, planned on scientific lines, have been built with large shed areas. All the new piers carry railroad tracks which are in turn connected with the public belt line. The equipment of dock cars also makes for efficiency. The ferry terminals are the largest in the world.

As in New York it is proposed to develop the entire port as one big terminal, combine the facilities of all the docks with their diversified industries and thus form one of the most spacious and best equipped harbors of the world. There are at present three great enterprises afoot for spanning the broad bay which separates San Francisco from Oakland and the mainland. One plan is to bridge the entire distance of seven miles. The trip by land from one city to another around the bay necessitates a journey of 120 miles. It is proposed to build a highway for this distance—a great undertaking, but one well within the possibilities of modern engineering.

Another plan is to construct a tunnel from shore to shore. The tunnel may rest upon a foundation of piles or be carried through a circular shield, as similar tunnels have been built under New York harbor. The traveling time between the two cities would be reduced and the great volume of automobile traffic would pass quickly and safely beneath the bay. An alternative plan is to span the bay by both bridge and tunnel, with the tunnel covering the greater part of the distance. Either of these proposals would necessitate one of the greatest engineering enterprises of its kind in the world, and the best engineering skill of the country has been enlisted in the enterprises.

Looking far into the future a general development of the broad expanse of water separating San Francisco and Oakland is contemplated. The plan is to enclose an area of thirty-five square miles between Goat Island and Oakland by modern breakwaters. The connection between Goat Island and San Francisco may be completed by a great subaqueous tunnel two and a quarter miles in length. A free and unrestricted channel would be left between these two points. This great enclosure will be one of the most spacious terminals in the world. It will provide almost unlimited manufacturing sites at sea level. The three cities about the bay, San Francisco, Oakland and Berkeley, would alike benefit from it, and its influence would be felt along the entire Pacific coast.

At Oakland an elaborate system of harbor development is now under way, involving an expenditure of several millions. A tube is being built under the estuary, obstructing bridges are to be removed, and the harbor deepened by dredging, thus assuring a great extension of its docking facilities. To-day cargo ships flying the flags of every great maritime nation may be seen at the Oakland docks. The harbor of Richmond is also being intelligently developed. Deep water channels are being extended to the shore line which will be lined with docks and warehouse facilities. The waterfront of Alameda also lends itself to extended development.

One of the largest and most modern maritime terminals in the world has been planned at Berkeley. The city is fortunately located on the mainland rim of the bay of San Francisco, directly east of the Golden Gate, and the waters here are landlocked. Complete engineering plans have been prepared for a harbor development to include four great units. The present plan contemplates the construction of a single unit which will provide 35,000 feet, or some seven miles of berthing space, with a depth of thirty feet at low water. This area will be served by wharves and sheds of modern design, covering 3,000,000 square feet, and filled bulkheads covering 3,500,000 square feet additional, with 1,500 acres of land available for railroad terminal and industrial plants. There are to be shipside tracks with classification yards for 2,000 cars. The ultimate harbor in this region, comprising four such units, anticipates an astonishing development.

Intelligently developed, San Francisco may some day have the largest and most efficient landlocked harbor in the world. Almost eighty per cent. of its great area affords safe anchorage. It is available for vessels of the deepest draught at all tides. The area selected for development at Berkeley is directly opposite the Golden Gate and readily accessible from the sea. Since it is on the mainland it may be the terminus for transcontinental railroads, thus avoiding ferrying from the mainland. California is confident of the future of her harbors, and by planning far ahead hopes to avoid the congestion which has proved so great a handicap in New York.

Virtually all the great ports on either seaboard of the United States have grown up about natural harbors. The harbor of Los Angeles, on the other hand, had to be created practically without assistance from nature. The problem solved here has its counterpart in some parts of Europe, notably in the Channel ports, but probably nowhere in the world has so much been accomplished in so short a time. Considered as an engineering achievement the harbor of Los Angeles is unique, and its expansion is still in progress.

Los Angeles grew up suddenly twenty-two miles inland. When she realized that a seaport was essential to her progress, she set about creating a harbor commensurate with her importance and future. A narrow strip of land twenty-two miles long and one quarter of a mile wide was annexed to the city, including the waterfront towns of Wilmington and San Pedro. An interesting parallel is afforded by ancient Athens, which secured a strip of land three miles in length reaching to its seaport, Piræus, and built a stout wall on either side of it for protection.

The location for constructing a great Pacific harbor was unpromising, being but an open bay protected on the west by a rather high headland and to the southward by Catalina Island. A great outer harbor was formed by constructing an extremely long breakwater, 11,000 feet in length, extending eastward from San Pedro. This long sea-wall affords shelter for a harbor with a frontage of five miles. The entrance at the end of the breakwater is 4,000 feet in width, with a depth of from thirty-eight to forty feet, thus affording access for the largest vessels. This outer harbor was enlarged by building other great jetties and constructing a deep sea terminal by extensive dredging. A spacious inner harbor is formed by excavating channels from the shallow tidal areas and filling in.

The harbor equipment includes a great turning basin, with a diameter of 1600 feet; the largest slip ever constructed, measuring 1800 feet in length, and an elaborate equipment of docks and warehouses with modern scientific machinery for handling freight. When the twenty-two-mile strip of land, reaching to the sea, was turned over to Los Angeles the city agreed to expend at least $10,000,000 in creating wharves and warehouse facilities.

Looking far into the future, plans have

been conceived for a great extension of the port to meet all possible demands. It is not definitely known what type of business must be handled, but docks and equipment are provided which can readily be adjusted to serve any purpose. The future harbor may occupy the entire bay, when the plans for a pier-head frontage of twenty-four miles may be extended to one hundred and fifty miles. The Federal Government has ordered a survey to extend the breakwater to assure a harbor six miles in length and two miles in width.

The growth of the harbor of Los Angeles has few parallels in the history of sea commerce. A generation ago no one anticipated the possibility of a busy port in this region. The city is the terminus of several great railroad lines tapping the natural resources of a rich region of the country. The completion of the Panama Canal suddenly brings New York within less than 5,000 miles by sea, serving as a link with Europe. The position of Los Angeles on the Pacific again affords direct communication with the East, and it is within easy reach of both coasts of South America. Here are the elements for developing a great world port. A study was made of harbor conditions throughout the world and, profiting by the experience of the past, a modern scientific harbor has been created.

Still another harbor capable of great development in this region is to be found at San Diego. It is a natural harbor and an ambitious scheme of development has already been conceived and in part realized. Anticipating the commerce of to-morrow a great pier and a bulkhead wharf were designed on modern lines. San Diego is aptly called the "first port of call" of the Pacific on the great trade route to and from the Panama Canal and the west coast of South America. It lies much nearer the ports of the Gulf, the Atlantic and of Europe than any other west coast harbor, and means to capitalize this advantage.

Had some maritime engineer of wide experience sat down to design an ideal natural harbor he could not have greatly improved upon the geographical lines of the port of Seattle. With comparatively little labor the natural harbor here has been greatly enlarged. Seattle is built upon a strip of land, varying from two to six miles in width, bounded on one side by Puget Sound and on the other by Lake Washington. Both form excellent harbors and Nature had nearly connected the two by a deep water channel. The connection was completed by building the Lake Washington Canal, but four miles in length, so that to-day the largest ships on the Pacific have easy access to the spacious landlocked inner harbor on the other side of the city.

The Puget Sound frontage contains a great basin which alone is as large as the combined area of the famous Royal Victoria and Edward dock basins of London. A second lake, connected with Lake Washington, in the heart of the city, is being transformed into a great terminal. A simple engineering problem was presented in joining the two lakes and bringing their waters to a common level. The depth of water is ample to ac-

Photo by Brown Bros.

AN AERIAL VIEW OF SAN FRANCISCO BEFORE ITS RECENT INTENSIVE DEVELOPMENT

AN ORE DOCK ON THE GREAT LAKES

Photo by Brown Bros.

LAKE STEAMERS WAITING TO ENTER THE "SOO" CANAL commodate the largest vessels on the Pacific. Several other smaller bodies of water in the immediate vicinity are connected up to this system, forming a great fresh water basin with more than one hundred miles of waterfront. Unlike other great natural harbors, such as New York, that of Seattle needs no dredging to keep it clear.

The city has expended some $16,000,000 in providing harbor facilities and modern equipment, which probably have no equal, in America at least. The system includes great municipal docks with piers, cargo sheds, concrete warehouses, cold storage plants, grain elevators, locomotive and powerful gantry cranes and a special harbor for a fishery plant for the Puget Sound and Alaskan trade. Two special piers have been constructed on modern lines for loading from ship to cars or the reverse. It proved to be one of the few harbors of the world so efficiently equipped that it could handle the unexpected demands of war commerce without serious congestion or delay. Seattle is very fortunately placed as regards its latitude and is nearer to the great ports of the Orient than any other American port. To-day sixty-four steamship lines enter this harbor.

One of the most persistent battles ever waged by harbor engineers against the sea has been fought in safeguarding the Columbia River channel at its entrance to the sea. Portland lies a hundred miles inland, and the river drains a rich valley for hundreds of miles. The great commerce which passes up and down the river was constantly menaced, however, by the treacherous bars encountered on reaching the sea. The June floods shifted the sand in many places, piling up these dangerous bars. In certain parts of the river shoaling was done by ordinary tides and currents and the channel could not be depended upon for the passage of even small craft. To-day Portland is a great world port, accommodating the largest vessels on the Pacific coast.

The problem was solved by building extended jetties under extremely difficult conditions. The workmen faced danger from the wind and waves exactly as have the builders of lighthouses in exposed positions. It was decided that a jetty extending out from Fort Stevens at the mouth of the river into the sea for seven miles would control the currents and tides and automatically deepen the channel. The construction known as the South Jetty was completed in 1913. As it was carried out to sea it was found that the entrance depths of the channel improved and remained permanent.

A second jetty known as the North Jetty was started in 1913 and after four years' work was carried to a point four miles from land. The Columbia River was thus successfully carried out to sea. The depth of the entrance channel was gradually increased from twenty-six to forty-three feet over a channel 4,000 feet in width. The cost of removing this bar incidentally was $6,000,000. As it stands to-day this construction is one of the great engineering achievements of its kind in the world.

Meanwhile a channel thirty feet deep was provided throughout the distance of one hundred miles which separates Portland from the sea, and secured by an elaborate system of dikes and jetties. To facilitate the work an immense hopper dredge, the *Clatsop,* was set to work. The dredge is self-propelled, like a ship, and especially equipped for this work. The sand was dredged and piled against special jetties built to retain it. The work was impeded by the freshets which here rise twenty-five feet. The ingenious system of dikes and jetties have proved permanent, however, and Portland enjoys a navigable channel at all seasons.

Portland harbor is especially well equipped with modern dock machinery for the rapid transhipment of bales, boxes and sacked goods, and has established several records for the rapid loading and unloading of several kinds of cargo. Its efficiency is largely due to a labor-saving cargo handling device known as the telescopic conveyor. The device makes it possible to load articles up to a weight of 500 pounds with amazing rapidity. It is a conveyor which works within a conveyor, and can be adjusted to reach out from the dock to a vessel as it recedes or raises with the changing of the tide.

A remarkable opportunity for the builders of canals is offered on the Columbia River. The stream rises in British Columbia but flows for a distance of 750 miles through American territory, finally emptying into the Pacific. It drains an exceedingly rich country, the development of which is only in its infancy. For long stretches the river is navigable, but a series of rapids interrupts the channel. The section between Vancouver, Wash., and Priest Rapids, a distance of 293 miles, is navigable, except for The Dalles and the Cascade rapids. These are readily passed by canals. The commerce of the Columbia River below Vancouver is at present 6,000,000 tons a year and this will be immensely increased with the extension of navigation inland.

A formidable competitor for the eastern trade is the Canadian port of Vancouver, eighteen miles north of the American boundary. Like other cities of the coast its growth has been very rapid. In 1865 three saw mills were erected here which formed the nucleus of a great lumber trade. Last year 550,000,000 feet of logs passed through this harbor. The island of Vancouver partly shelters a broad outer harbor behind which lie in turn a central and an inner harbor of considerable size. Some fifty square miles of water area are available, with a shore line almost one hundred miles in length. Vancouver enjoyed a great boom during the World War, and is capitalizing her good fortune. The port is being rapidly developed along modern lines to berth deep sea vessels and provide every facility for working cargoes.

CHAPTER IX

THE HARBORS OF THE GREAT LAKES

BY a fortunate chance the vast inland seas of America touch the great productive areas of the Northwest and make possible an immense waterborne commerce to the south and the east. The group of five lakes provides navigation for vessels with twenty-foot draught from the head of Lake Superior to Buffalo, a distance of 1,023 miles. They form a great national highway for the shipment of products of many kinds. The cost of carrying freight per ton per mile had been reduced a generation or more ago to twenty-three one hundredths cents and it finally fell in 1898 to but eight one hundredths. Since then the rate has risen somewhat, but still remains extremely low. The actual saving in transporting this freight by water rather than by railroad is about half a billion dollars a year. Here is the secret of the growth of the cities of the Great Lakes.

The low freight rates are due to the marvelous efficiency of the freight craft on the lakes and the improvement of harbor facilities. The vessels designed for this trade and the dock equipment for handling special cargoes in this region are unrivaled. There are at present three classes of steamers plying the Great Lakes devoted respectively to passenger, package freight and bulk freight transportation. All three classes of vessels have had a remarkable development. In 1894 there was not a single vessel on the lakes with a carrying capacity of over 5,000 tons. The modern bulk freighter measures 600 feet in length, fifty-eight feet in beam, with a draught of twenty feet and carries 14,000 tons of freight. The loading and unloading of these craft is facilitated by their having unusually large hatches spaced at multiples of twelve feet throughout their length.

The rapid development of commerce on the Great Lakes may perhaps be visualized by comparing the traffic of the "Soo Canal" with that of the great canals of the world. An enormous tonnage under many flags regularly passes through the Suez Canal, the focal point of innumerable trade routes, in the course of a year amounting to 27,000,000. During the single month of August, 1922, the tonnage of the "Soo" was 22,000,000. Through this lake canal (Sault Ste. Marie) regularly passes a tonnage greater than that of the foreign commerce of New York, or nearly three times that of the combined tonnage of the Panama and Suez Canals.

The importance of a canal at this point was of course obvious from the days of the first settlement of the region. The St. Marys River, connecting Lake Huron with Lake Superior, lent itself to development. Its width and depth were ample but it was obstructed with rapids. Docks were built here as early as 1797 by one of the fur companies. In 1855 a canal around the rapids was built, 5,700 feet long, navigable by vessels drawing fifteen feet of water. The Federal Government in 1881 widened the canal to one hundred feet and further deepened it. The traffic passing through the canal grew so rapidly, however, that the Government in 1908 again widened the waterway, built new locks 1,350 feet in length, and deepened it to twenty-five feet at extreme low water. On account of the long winters the canal is open to navigation on the average less than nine months in the year. A photograph of a fleet of bulk freight ships awaiting passage through the canal is reproduced on another page.

It is a great tribute to America's mastery of maritime engineering that some of the greatest ports in the world are to be found on the Great Lakes. The artificial harbors built under Napoleon in exposed positions, especially those along the English Channel, have been admired for a century. The Great Lakes present even more baffling problems and here such construction has often been carried out on a far more ambitious scale. The shipping interests of the lake cities are far more diversified than in Europe, and call for greater ingenuity in constructing harbors which will function safely and efficiently.

The shipping and harbor conditions on the lakes often vary widely from those of coast ports, but the underlying principles remain the same. In some cases it has been impossible to choose an advantageous natural site for building a harbor, since the cities have grown up more or less by accident, and the harbor engineers must make the best of very poor locations. They have been obliged to work in many instances absolutely, without natural protection of any kind from the attacks of the storms or ice. The ice problem in many of these ports is almost without parallel. Within the past few years and especially since the close of the World War much more ambitious plans have been made for coördinating shipping facilities on the Great Lakes. The port development of the near future promises to far surpass the efforts of the past. The most remarkable lake port development to-day is found at Chicago, Buffalo, Cleveland, Milwaukee and Duluth.

The great artificial harbor of Chicago is designed with the confidence that it will be the greatest inland port in the world. The maritime engineers intrusted with this problem faced a difficult situation. The shore line has no natural protection and the waters of Lake Michigan are often extremely treacherous. The harbor is wholly artificial, and is formed by breakwater construction.

The first step to construct a harbor for navigation consisted in improving the Chicago River by jetties, extending from its mouth far out into Lake Michigan. The outer harbor was afforded shelter by building enormous cribwork breakwaters. Two detached breakwaters were then built between these at the harbor entrance, parallel to the shore, and each 4,000 feet in length. The southeast breakwater, which is ingeniously placed at an angle, is 3,000 feet long.

These extensive barriers shelter an area 455 acres in extent, of which 125 acres is reserved for piers and ships. A refuge harbor has been constructed by building an exterior detached breakwater 5,432 feet in length about a mile to the northeast of the harbor. This great system of breakwaters is constructed of strong timbered cribwork. It was floated into position in lengths of one hundred feet, sunk to the bottom and filled with stone. Ordinarily the square form of harbor proves most satisfactory, but at Chicago the protected area is rectangular in form. Famous artificial harbors created in similarly exposed places obviously appear small and ineffectual by comparison with this immense work.

The lake front of the city has been laid out in a system of five great harbor districts which will provide facilities for traffic for years to come. The first link in this comprehensive scheme is the great municipal pier which now accommodates all passenger and light package freight business. These facilities at present attract 15,000,000 tons of shipping annually, while 5,000,000 more tons are deflected to neighboring ports.

Another great artificial harbor designed for industrial development will be built at Lake Calumet. The entire lake, thirteen miles in length, is to be dredged and filled to make land for factory sites. There will be a main basin, 1,600 feet wide and 12,000 feet long, with connecting channels covering an area of 471 acres. The combined water area of the anchorage channel and slips will be 693 acres. Five great harbors in all have been laid out in anticipation of the traffic of Greater Chicago.

In planning her harbor, Chicago looks forward with confidence to gaining a large share of the future commerce of the country. Her phenomenal gain in population and wealth indicates further progress at the same rapid pace. Chicago, it is argued, holds an important strategic position at the intersection of the great east and west traffic routes of the country. A large share of the country's commerce passes her in crossing the continent. In time, it is believed, the volume of this commerce will exceed that now handled either on the Pacific or Atlantic seaboards.

Chicago may have ultimately three routes by deep water channels to the sea. The city has already profited by the Erie Canal, which forms an outlet by way of the Hudson River to the Atlantic. The opening of the proposed St. Lawrence Ship Canal will give her direct access to the Atlantic without transhipping cargoes. The Chicago Drainage Canal may be the first link in a continuous chain of broad canals and rivers leading to the Gulf of Mexico and the Atlantic, and via Panama to the Pacific.

The opening of either of these proposed ship canals will make it possible for freight vessels from all parts of the world to load and unload at Chicago docks. The expense of transferring cargoes will be eliminated. Both freight and passenger services will then be installed, rendering Chicago independent of New York or New Orleans, which will no longer be able to take toll of the immense tonnage which passes through them to-day. Chicago will become a great world port.

It is only a question of time when the population of the middle West will surpass that of the East. The products of this vast area, agricultural, industrial and mineral, will then far exceed those of the seaboard to-day.

Following this line of argument it is urged that Chicago is destined to pass New York in the volume of its commerce and manufacture, and, in turn, in population and wealth. New York, meanwhile, it is argued, will lose a great source of wealth in the commerce now carried overland by railroad from the West en route for Europe which will ultimately pass directly by water. Chicago is doubtless destined to become the greatest inland port in the world.

The great artificial harbor at Buffalo in some respects even surpasses that of Chicago. Like other lake ports Buffalo has a combination of artificial enclosures, formed by enormous breakwaters, and a river channel dredged and protected at great outlay to meet the demands of growing commerce. The Buffalo River is guided into Lake Erie by parallel jetties similar to those at Chicago. The harbor has been greatly enlarged by a protecting breakwater of cribwork. It is detached and extends along the shore for a distance of 7,600 feet, or about a mile and a half. The crib rises eight feet above the level of the lake, under normal conditions, which gives some idea of the magnitude of the undertaking. In severe storms the water dashes over the breakwater, burying it from sight.

An inner harbor, as it may be called, contains most of the facilities for transhipment of cargoes. Here are to be found elaborate freight and passenger docks and local landings. Part of the waterfront is served by a belt line which will be extended. The inner harbor contains the first unit of the new barge canal terminal. The old channels have been enlarged into a shipping channel capable of accommodating large vessels. A useful frontage of some fifty miles is available for future use. The present terminal and the enlarged facilities planned for the future are to be coördinated with the industrial sections of Buffalo. Since the new barge canal starts from Buffalo, the port seems assured of a great extension in the future, judging by the amazing record of the Erie waterway.

A surprisingly large tonnage of goods is transhipped on the Buffalo docks, considering the comparatively limited accommodations of the harbor, as compared with the records of most seaports. The speed with which ships are loaded and unloaded is not due so much to superior dock equipment as to the fact that the lake traffic, or much of it, is carried in vessels which have been designed for the purpose. Some of the loading and unloading records are amazing. A vessel carrying 14,000 tons of coal can be unloaded in three hours, and a vessel laden with 14,000 tons of iron in ten hours. Package freight is handled at the rate of 400 tons an hour. One of the most interesting features of the Buffalo docks is the gravity bunkers for handling coal. A car filled with coal is quickly raised above a system of pockets and chutes and the coal guided into the ship beneath. Each car is weighed on its way to the pocket, and again when returning empty, thus giving the exact quantity of coal. The operation includes the screening of the coal as it descends.

The artificial harbor at Cleveland has been developed to keep pace with the rapidly increasing commerce of the city. In 1908 it comprised two distinct ports, an outer harbor, constructed by the Federal Government, and an inner harbor, built by the city. The outer harbor was formed by two breakwaters, enclosing an area two miles in length by 1,700 feet in width. The main entrance is 700 feet wide and lies opposite the mouth of the Cuyahoga River some 1,350 feet distant. The depth of the water in this harbor is twenty-one feet. By recently extending the breakwater three miles the capacity of the harbor was doubled. A concrete jetty 1,054 feet long was also built. The river can furnish thirteen miles of safe dock frontage for the largest vessels in the lake trade.

Milwaukee has an excellent harbor which has been skilfully developed. The inner harbor has a depth of twenty-one feet and is formed by the mouths of three rivers entering the lake. The channel of the Milwaukee River is protected at its mouth by piers. The outer harbor to the north of the main entrance has an area of 650 acres. It is partially protected by a great breakwater 8,610 feet in length. The outer harbor has two entrances, one 1,650 feet in width, the second 360 feet in width.

Elaborate plans have been made since the World War for developing the harbor of Toronto, which will make it one of the greatest ports on the Great Lakes. The harbor is to have a general navigable depth of twenty-four feet, which will accommodate the traffic of the lakes, and channels thirty feet deep in anticipation of the Atlantic liners which will some day find their way here. A great breakwater is to be constructed, protecting an area of fifteen miles. A series of great docks and wharfs will be constructed on modern lines, equipped with efficient machinery for working cargoes. In the shallow areas some 32,000,000 cubic yards of sand will be removed to create land areas of over 2,000 acres. The work, commenced in 1921, will be completed in 1927.

CHAPTER X

MODERN GULF TERMINALS

ARE the Gulf ports destined to lead those of the Atlantic and Pacific a generation hence? Several of the great harbors along the Gulf of Mexico are being built with the hope and confidence that they will be the focal points of the great trade routes of the future. To-day the Gulf of Mexico carries larger and more valuable cargoes than ever floated on the Mediterranean Sea at any period of her long history. New Orleans has come to occupy the second place among American ports; Port Arthur the third place, and Galveston the fifth position.

The arguments advanced by the builders of the Gulf ports for their hopes of future supremacy are surprisingly convincing. It is pointed out that the total area of the United States and its territories (not including Alaska), lying west of the Mississippi, is 1,840,592 square miles, while but 1,187,859 square miles lie east of that river. In other words, the West is about one and a half times larger than the East. When the center of population, in its western progress, crosses the Mississippi, the products of this region will probably be greater than those of the Atlantic seaboard, bounded on the west by the Appalachian Mountains, or of the Pacific west of the Rockies.

The immense commerce from this region, following the lines of least resistance, it is argued, will inevitably drain to the south, finding its outlet in the deep water harbors of the Gulf of Mexico. The growth of these gulf ports has been phenomenal. To-day the cotton shipped from Galveston in a large measure clothes the world, and the grain which finds an outlet at the same port goes far to feed the world. If the dream of a ship canal connecting Chicago and the Great Lakes with the Gulf is realized, the great Northwest may ship via the Gulf ports. Several great harbors will be required to handle this commerce, and doubtless a remarkable future awaits them. In the past the great trade routes of the United States have run for the most part east and west. The Gulf ports look forward with confidence to a day when this great commerce will flow north and south.

The growth of these Gulf ports is largely due to their efficient docking and cargo-handling facilities. Many large ships in the Gulf trade are designed for handling special cargoes. The various decks may be reached by ports as well as through hatches. Many forms of cargo are quickly and cheaply transhipped by ramps and gangways and endless motor-driven chains carrying hand trucks. Cargo in remote parts of the decks is loaded upon trucks, then wheeled within reach of the horizontal conveyor which catches them up and transfers them in a few seconds to the dock. Loading is the reverse operation.

Long before the day of railroads, New Orleans had become a great port. For many years she has held the exclusive trade of the Gulf of Mexico. To-day New Orleans occupies an immensely valuable strategic position in her fight for domestic and world commerce. Standing as she does at the gateway to the Mississippi River she takes toll of the immense wealth of commerce which seeks an entrance to the sea, as well as of that which returns. This great hinterland comprises twenty-six States, containing fifty per cent. of the population of the country. In this broad valley eighty per cent. of the crops of the continent are grown, while from seventy to eighty per cent. of the mineral wealth of the country lies buried here. More than half the goods manufactured in the United States come from this general region. New Orleans is also the focal point of many great railroad systems.

New Orleans lies 800 miles nearer the Panama Canal than New York, and therefore enjoys a great advantage in the trade with the Orient and either coast of South America. Since the World War South America looks to the United States for food and many products she formerly sought in Europe, and she must sell many things to

America which she formerly sold in Europe. To-day ninety steamship lines operate from New Orleans to all parts of the world. More than 5,000 vessels enter and leave her harbor each year with a total tonnage of 14,000,000. A great era is opening in the expansion of her trade. The rise of the port of New Orleans to the second place among American harbors has been a remarkable achievement. Her location on the Mississippi River, 110 miles inland, would be expected to be a handicap. On the other hand the unusual configuration of the land and natural waterways in her vicinity, when properly utilized, have proved an immense advantage and still hold wonderful possibilities of development.

New Orleans has been building for the future and making the most of her opportunities. The scientific development of her harbor has attracted the attention of harbor engineers throughout the world. The Mississippi River has been developed and equipped with modern harbor machinery for a distance of twenty-one miles on both shores, thus giving the city a river frontage of forty miles. The river throughout the port development is from one half to three quarters of a mile wide, and from forty to one hundred feet deep. The deep water area is more than seven square miles in extent. She is readily the first fresh-water port of the country, in size, equipment and the value of her commerce. An almost unlimited number of vessels can here be accommodated, and it is a two-way port, since her import and export tonnage are almost exactly equal.

The mechanical equipment of New Orleans, considering her problems, is unrivaled. Her great cotton warehouse, erected at a cost of $6,000,000, will accommodate five ships at a time. The dock equipment makes it possible to load 7,500 bales of cotton per day and handle 3,000,000 outgoing bales of cotton a year. New Orleans is the only great Gulf port which enjoys adequate railroad connections, and the docks are well served with an elaborate system of waterway, railroad and public belt lines.

For storing the cotton a double-decked, reinforced concrete wharf has been constructed, with storage facilities for 60,000 bales of cotton, thus increasing the harbor facilities to 250,000 bales. The docks were designed to make possible direct loading from freight cars to ships or the reverse. The latest loading, unloading and transportation devices were installed. This has served to increase the speed of the freight movement forty per cent. The first wharf cranes of their kind in the United States were installed here. The harbor machinery makes it possible to handle at one time one hundred freight cars and four vessels of 10,000 tons. It is estimated that at the present rate of growth New Orleans will handle an immense volume of freight, some fifteen years hence, rivaling the capacity of New York.

The outstanding feature of her harbor improvements have been the construction of a great "Navigation Canal," five and a half miles in length, to connect the present harbor on the Mississippi River with the spacious waters of Lake Pontchartrain, lying on the other side of the city. Profiting by the experience of other cities in building such waterways the canal is a model of its kind. With a draught throughout of thirty feet its channel is 300 feet wide at the surface. It is faced throughout its length by slips and docks of modern design, equipped with the most efficient machinery for freight handling. A great inner harbor is thus formed, capable of unlimited development.

The industrial canal has by far the largest lock in the United States. The great locks of the Panama Canal have been frequently praised as an achievement of American engineering, but the difficulties overcome at New Orleans were far more baffling. It was necessary to work in treacherous quicksands and fight the inrush of water at various levels, and upon so unstable a foundation to build locks capable of accommodating heavily laden sea-going vessels. For years the construction was considered impossible.

In designing the lock it was necessary to allow for the great variation of some twenty feet in the level of the Mississippi River.

The locks must be built fifty feet in depth. The ground where the excavation was made was a treacherous silt deposited by the river, alternating with quicksand. On every attempt to dig into this mixture the sides quickly caved in. Beneath this soil marsh gas was constantly being forced upward, creating "boils" in the floor of the excavation, and frequently blowing up the bottom. The pressure of the collapsing sides also served to squeeze upward the deeper layers of quicksand.

The most efficient dredges could not get below a certain depth, for the quicksand would flow in faster than it could be removed. It had been planned to build a foundation by driving piles into the soft floor, but it was feared that the treacherous soil would not supply sufficient friction to hold them in a position to sustain the enormous weight of the lock, the water and the ships passing through it.

The first step in solving the problem was to calculate the pressure which must be counteracted. This determined, the force was balanced by the holding power of steel and pine, and the work was done on an unprecedented scale. First a hole was dug 350 feet by 1,500 feet, with sides very gently sloped in the proportion of one to four. It was believed that this angle would prevent slides and outwit the quicksands and the gas "boils." When the digging was commenced a cofferdam was sunk completely around the lock as a further prosecution against quicksands. Further in a second ring was sunk. The exact nature of the soil and the power of the marsh gas were unknown quantities at these lower depths.

As the work progressed the sand proved to be much more liquid and the gas pressure greater than had been anticipated. The quicksand ran through the double lines of defense like water through a sieve. Despite the gentle slope of the sides the walls caved in. Sand boils developed like an epidemic and quickly grew more virulent and finally the floor of the excavation blew up. The workmen were in danger of their lives from this volcano beneath them. It was a critical period and victory was won only by an ingenious expedient.

One of the largest cofferdams ever constructed of steel was quickly built on the site. Concentric rings of steel were driven down deep into the treacherous soil. Water was then pumped in to counterbalance the pressure of the earth at the sides and the pressure of gas below. As a further precaution fifty-six artesian wells were driven down inside the enclosure. The result was watched with great anxiety, but when the site was drained the walls held.

Then began the actual construction work of driving 2,400 piles, each sixty feet in length, to form a foundation on the floor of the lock. Since these were driven far below the surface their lower tips reached one hundred feet below the level of the "ground." Over these a concrete filling from nine to twelve feet thick was put in to form the floor of the lock. The walls of the lock are thirteen feet thick and are reinforced by 6,000 tons of reinforcing steel. Some idea of the magnitude of the work may be gained from the statement that 125,000 barrels of cement were used in the work. The lock alone cost $7,500,000. It would be difficult to conceive of a more unpromising site for such construction, yet to-day great ships pass serenely through this artificial river above the treacherous sands.

A unique feature of the great artificial harbor at New Orleans is the disappearing river which is carried beneath the industrial canal. Nowhere else in the world has so ingenious an application of hydraulics been carried out on so large a scale. The city of New Orleans lies below the level of the adjacent river and lake, and may be compared to a bowl or dish of which the levees built against the river and lake form the rim. There is no natural drainage, and the rainfall is very heavy. Heroic efforts must be made to empty this bowl or at each rainfall the city would be submerged.

To solve this problem New Orleans has built its famous drainage system. Six great pumping stations have been built on the sides of the river, connected with each other by canals. The pumps have a capacity of 10,000 cubic feet of water a second, or 7,000,000 gallons a day. In other words they could daily remove a lake one mile square and thirty-five feet deep. To get rid of this immense volume of water, it is necessary to siphon it under the industrial canal which lies in its path.

The drainage canal approaches to within one hundred feet of the industrial canal, when it suddenly dives forty feet underground, passes under the shipway and comes to the surface on the other side, where a powerful pumping station raises the water to a still higher level. The siphon is an amazing construction of steel and concrete, capable of handling the rainfall of a cloudburst. The water passes through eight sluice gates, each six by ten feet, opening close to the water chamber. These are operated in turn by hydraulic cylinders of the most approved type. The siphon is provided with eight manholes to allow workmen to enter the chambers to make repairs. The commerce of the port passes back and forth in the canal above this siphon undisturbed.

Confident of the future the harbor is being planned on broad lines. A plan was suggested by Gen. George W. Goethals to dredge a channel through Lake Pontchartrain and the marshy land to the Gulf of Mexico, which would shorten the route to the sea some fifty miles. The cost of construction will be $10,000,000. Such a waterway would rank, in regard to the commerce it would carry, with the Panama or Kiel Canals, and be an invaluable link in the proposed intercoastal canal.

This great canal to the sea will be sixty-five miles in length. It will run through low-lying, level country, which offers no serious engineering problems. From this main waterway lateral canals can be dredged as they are needed, so that the entire distance may some day be the site of a great commercial development. Factories may some day line this waterway, able to receive at their doors foreign cargoes from ocean liners, and domestic cargoes from barges which may navigate 2,000 miles or more of inland waters.

The development of Galveston harbor has been a unique achievement in engineering. The difficulties faced were almost insurmountable, yet within a comparatively few years, working with unpromising materials, the greatest port of its type in the world has been developed to a tonnage ranking it fifth among American ports. The entrance to the harbor was long obstructed by a bar of fine sand, which when wet became a quicksand constantly shifting under the action of the currents. Dredging did little good since the sand refused to lie still. In 1874 work was commenced on a great jetty, seven miles in length, in from five to eighteen feet of water. The position was very exposed and the work progressed under great difficulties. It was finally found necessary to build other jetties to form a dependable channel across the bars. To-day vessels with a draught of thirty feet can be accommodated in the harbor at low water.

The position of the harbor is in many respects extremely favorable. It stands at the focus of an immense system of rail and water transportation. The docks are less than one hour's sail from the open sea. The port is near the geographical center of the greatest producing area of the United States and is the nearest port for an immense region comprising some two fifths of the total area of the United States.

Recognizing the possibilities of the port a careful study was made of the facilities of great world ports, and, profiting from them, plans for Galveston harbor were prepared. The docks were designed for the special work expected of them and the machinery and equipment was the best available. Largely as the result of this preparation Galveston is to-day the greatest cotton port of the world, and the second wheat port of the United States. It affords a striking example of the advantage of providing scientific port equipment. The harbor improvements at Galveston have cost over $10,000,000.

The port of Mobile has also shared in the surprising development of the commerce of the Gulf of Mexico. It possesses an excellent landlocked harbor which affords practically unlimited anchorage for ships. A channel, thirty feet deep, has been developed to the Gulf of Mexico, affording safe navigation for the largest steamers in the Gulf trade. The improvements of the harbor and channel have been made at an outlay of some $10,000,000. Here are all the elements necessary for the development of a great world port. To-day twenty-five regular steamship lines carry the commerce of Mobile to many American ports, to Europe, South America and Asia.

The list of American ports in the order of their tonnage contains no greater surprise than the position accorded to Port Arthur. That it should rank third among our ports, standing above Philadelphia, San Francisco and Chicago, seems astonishing, even to well-informed business men. The Sabine District, including the harbors of Port Arthur and Beaumont, lead all other American ports in handling petroleum products. In the course of a year some 12,000,000 tons pass over the Sabine bar.

The Federal Government has expended to excellent purpose $80,000,000 in improving the ports of the Gulf of Mexico.

CHAPTER XI

EVOLUTION OF THE CANAL

WHEN our first glimpse of the planet Mars revealed a mysterious criss-cross of many lines we at once jumped to the conclusion that these tracings might be canals. The lines enclosing these groups were interpreted to be the boundaries of continents and seas, and the eye involuntarily traced possible trade routes between the focal points of these waterways. We may speculate at random as to what grotesque creatures inhabit that remote planet and what may be their means of locomotion, but we cannot conceive of a civilization without commerce and trade routes.

The building of canals was among the earliest engineering achievements. The ease with which a boat, however heavily laden, glides upon the water, compared with the tedious labor of human or animal land transportation, was of course obvious even to primitive people. The first artificial waterways were doubtless merely ditches for irrigating the land. Considering the primitive tools used by the ancients, the early development of canal building was remarkable. A system of canals had been built by the Egyptians, it is believed, fully 9,000 years B. C., which served to carry their commerce overland.

Canals were built many centuries before the Christian era, not only in Egypt, but in Chaldea and China. Since there was little or no communication between such remote regions at the time, the canals must have been developed independently to meet the demands of these different regions. The first workable system of canals definitely recorded is that of Babylon. Built in 1700 B. C., they served a large area, and helped materially to build this great city of the ancients. They fell into disuse, but were restored by Nebuchadnezzar and made available for merchant vessels in 600 B. C. Herodotus describes them as one of the wonders of the ancient city. Even to-day they may still be traced among the desert sands.

It seems probable that these early canals must have served as a model or an inspiration for the engineers who attacked the Suez Canal problem at about the same period. The skill of these early canal builders must have been considerable, for they succeeded with very primitive machinery in actually connecting the Mediterranean with the Red Sea by way of the Nile in 1380 B. C. What is more, the original Suez Canal is said to have been in operation for nearly fifteen hundred years. On the ascendancy of the Mohammedans in Egypt the Caliph Al-Mansour ordered the destruction of the canal.

It is curious that the Romans, who were so tireless in building roads and aqueducts, left no important canals in any part of their vast empire. The old records show that the Cæsars made many ambitious plans for building canals, but were too busy with their wars to carry them out. A Roman canal connected the Rhone with the Mediterranean in

Gaul, and a second artificial waterway ran from the Tiber to the sea. They also constructed two dikes in England, the longer, the Foss Dike, running from Lincoln to the river Trent, being eleven miles in length. This was deepened in 1121 and is still in operation.

Despite the wars and commercial paralysis of the Middle Ages there was considerable activity in canal building. Charlemagne joined the upper Rhine and Danube by canal, and planned a second canal between the Danube and the Main. The first lock canal is believed to have been built in Holland in the fifteenth century, although Italy solved the problem at about the same time.

A great forward step in the science of canal building was taken by the building of the French canal between the Bay of Biscay and the Mediterranean, 148 miles in length, completed in 1681. China already had her "Grand Canal," finished in the fourteenth century, which continued for centuries to form an important artery of commerce. Marco Polo reported that an ingenious system of inclines was used on the Grand Canal for raising vessels from one level to another.

During the past two centuries the activity in canal building throughout Europe has been amazing. Taking advantage of the innumerable seas, gulfs and bays which indent the entire western and southern boundary of the continent, a vast network of artificial waterways has been constructed, crossing and recrossing an enormous area. In several countries of western Europe more than half the total tonnage is borne on these artificial waterways. The rapid rise to wealth and power of England, Holland, France and Germany has been due in large measure to the cheap transportation thus made possible.

A score or more of canals had been planned in America while the territory they were to traverse was still a wilderness occupied by unfriendly Indians. The early settlers from Holland, as might be expected, began to build forts and canals at about the same time. A canal large enough to accommodate small vessels was dug through the Broad Street in New Amsterdam. Later a canal divided a cross town street in New York which is still known as Canal Street. A number of small ditches and canals were built in these early days along the Atlantic seaboard, and many more, some of a very ambitious nature, were confidently projected.

The early settlers along the Atlantic seaboard found refuge as a rule at the mouths of rivers, where the first settlements slowly grew. As the population increased the rivers were explored and settlers moved gradually up the streams. Later a flanking movement set in from the Gulf of Mexico following the valley of the Mississippi River. The pioneers from Europe were of course familiar with the value of canals and soon sought to solve the transportation problems of their new land by this ancient device.

With the growth of population west of the Alleghanies the need of a canal connecting the Great Lakes with the Atlantic soon became obvious. It is a great tribute to the enterprise and vision of the early settlers that this need should have been recognized and the route explored as early as 1724, two centuries ago. The Surveyor General of the Colonies, Cadwalader Colden, who was later Lieutenant Governor of the Colony of New York, made the journey and declared that the route would be the "scene of inland navigation such as cannot be paralleled in any other part of the world." Various plans were discussed from time to time, but the work was too ambitious for the narrow resources of the Colonies at the time.

At the close of the Revolution in 1783, Washington personally surveyed the proposed route of the canal. He brought to the task a practical knowledge of surveying and engineering, as well as his vision of the future. Accompanied by Governor Clinton and Alexander Hamilton, Washington covered 680 miles on horseback to study conditions at first hand. In commenting on the trip he wrote: "I could not help taking a more extensive view of the vast inland navigation of the United States, and could not but be struck by the immense extent and and importance of it and of the goodness of Providence which has dealt its favors to us with so profuse a hand. Would to God we may have wisdom enough to improve them. I shall not rest contented until I have explored the western country and traversed these lines or a great part of them which have given birth to a new empire."

Meanwhile many routes were suggested to connect the Atlantic seaboard with the Great Lakes and the Ohio Valley. Pennsylvania had schemes for canals reaching westward. The plan known as the Chesapeake and Ohio project sought to solve the problem by connecting the Potomac River with the Ohio system. It was promoted by Washington in 1774 and built in 1785. The company failed, but was reorganized in 1828. The canal as it now stands cost $11,000,000.

Although the machinery available for building canals in these early days was primitive and the funds available very limited, astonishing progress was made nevertheless. Two canals were completed as early as 1794, and half a dozen more before 1830. The two eighteenth century canals were built in Virginia and Louisiana. The first, the Lake

Drum Canal, was twenty-three miles in length, an astonishing engineering feat for the period. It was built seventy feet wide and nine feet deep and its cost of construction with improvements was over $3,000,000. The Old Basin Canal in Louisiana, also opened in 1794, was five miles long with a width of eighty-four feet and a depth of five feet and cost about a quarter of a million dollars.

It was not until 1822 that a canal was completed in the northern States, when the Champlain Canal was opened, and the total length of the waterway was sixty-two miles, although the canal itself was but twenty-three miles long. Its depth of twelve feet and a width of one hundred and fifty feet anticipated the growth of shipping in this region for many years to come. The cost of construction, $21,000,000, set a new standard for such investments. Three years later the Erie Canal was formally opened.

The early canals in the order of their completion were the Lehigh Canal, 1821; Schuylkill Canal, 1829; Delaware & Raritan Canal, 1834; Harvey's Canal, La., 1835; New Basin Canal, La., 1836; Company's Canal, La., 1836; Morris Canal, 1836; and the Cayuga & Seneca Canal, 1839.

In the early days the canal boats carried both passengers and freight. With the coming of the railroad this leisurely method of travel soon disappeared, never to return. A few old prints of the combined passenger and freight canal boats are still preserved. The upper deck of the boat was supplied with seats, while for long journeys sleeping accommodations were provided below decks. The propelling force was mule power, and the rate of progress rarely exceeded two or three miles an hour. The canal, however, often traversed wild regions of country where the roads were primitive and in a more leisurely age these boats afforded a delightful means of locomotion. The passengers drowsed through the long days beneath the shade of shore-side trees, or slept peacefully through the night without a suggestion of jarring or vibration.

If the boats were very heavily laden two

Photo by Brown Bros.

THE AFTER DECK

DOCK EQUIPMENT FOR LOADING ORE AND COAL

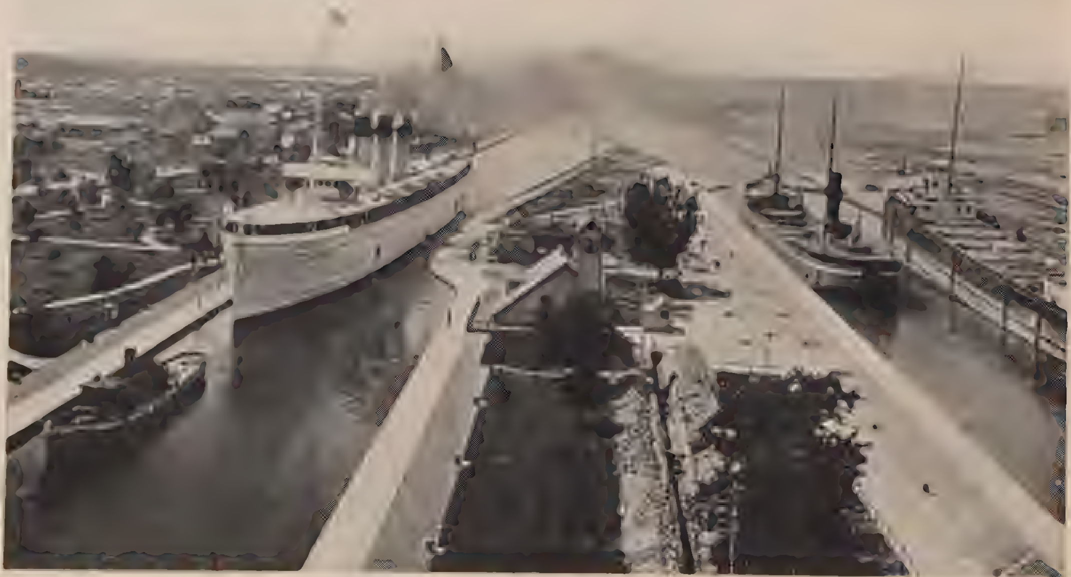


Photo by Brown Bros.

THE ENTRANCE TO THE "SOO" CANAL

mules were hitched in tandem. The animals were driven along the interminable tow paths, usually by boys. The work was considered a creditable occupation and a stepping stone to advancement. To have begun life by driving the mules on a canal lent much the same distinction as being born in a log cabin. In several presidential campaigns the candidates claimed the support of voters for having served in this humble capacity, and at least one such candidate reached the White House.

The canal boat has lent a pleasant touch of life and color to many landscapes. The problems of navigating such craft, being simple, were entrusted to a single mariner, usually with the rank, or least title, of captain. Space was generally found in the ample hold for a cabin suited to his needs and commonly his family accompanied him on his voyages. The afterdeck of the boat often presented a very domestic scene, with a miniature garden, awnings, chair and frequently the family laundry flung to the breeze. Life aboard such craft must have a little of the quiet and exclusiveness, if not luxury, of that on a private yacht. In the course of the season these boats traversed hundreds of miles of quiet canal and rivers and visited many busy cities and harbors.

There are those who will regret the passing of the patient mule and the deliberate progress of the century-old craft, gliding serenely past hill and dale. The canals of to-morrow will doubtless be crowded with strange looking craft, hurrying along at vastly increased speed, and carrying the discordant note of steam whistle and wreaths of black smoke and gasoline fumes through the quiet countryside.

The great Erie Canal project was the first to connect the Atlantic seaboard with the Great Lakes. With the subsequent achievements of the canal in mind it is interesting to read in the early records that it was difficult to obtain an appropriation of $125 to enable the engineer, Christopher Cole, to complete his surveys of the route.

It is generally admitted that the Erie Canal gave New York the necessary impetus to make her the metropolis of the country. As late as 1800 Philadelphia confidently expected that she would be the principal city of the Atlantic seaboard. At the close of the Revolution, New York had dwindled to a struggling town of 10,000 inhabitants, with her industries prostrate. With the opening of the canal the tide quickly turned.

On the completion of the waterway between Albany and Utica, a distance of one hundred miles, the freight rate was suddenly reduced from $1 to thirty cents a ton. Before the waterway was completed the tolls collected amounted to more than $1,000,000. By the year 1832 the tolls had completely paid the cost of the canal, $7,000,000. For years thereafter the tolls from the canal were sufficient to pay the entire cost of the State Government. From 1837 to 1907 the canal carried 300,000,000 tons of freight, valued at $10,700,000,000, or an average per year of 4,000,000 tons worth $150,000,000.

After the completion of the Erie Canal a frenzy of canal building swept the country. The canal enthusiasm spread down the Atlantic coast and as far west as Illinois and Wisconsin. Canals were dug through the wilderness of the south and west, developing new regions. Later with the growth of railroad building the rails often paralleled the canals and competition became very keen.

The greatest artificial waterway in America, if we except the Panama Canal, is the New York Barge Canal. Throughout its long channel ply canal craft, some from 130 to 150 feet in length, and twenty feet or more in width. In place of the deliberate mule harnessed to a single boat traveling two or three miles an hour, these waters are now traversed by long tows or many types of self-propelled boats. The modern steel locks, measuring 300 feet by 45 feet, readily raise or lower the largest canal craft.

The Barge Canal is one of the outstanding engineering feats of its kind in the United States. It involved the entire reconstruction of the famous Erie Canal. Much of the old channel has been used and widened, eliminating the old tow path. The completion of the canal makes possible a continuous trip by large craft from the Great Lakes to New York, a distance of about 500 miles. The total mileage, including the canalized rivers and lakes, is 382. Connecting spurs have been constructed to Syracuse and Rochester. The canal drains a densely populated industrial district. Within twenty miles of the waterway live more than 8,000,000 people or eighty-seven per cent. of the entire population of New York State.

The Barge Canal has been provided with eight terminals which greatly increase its general efficiency. There was a time when canal traffic was so much more economical than any other form of transportation that the terminal facilities could be neglected. To-day the rivalry between the canal, railroads and motor trucks is so keen that the cost of transhipment from canal boats of every type must be reduced to a minimum.

Heretofore the picturesque craft which had passed through the canals unloaded their cargoes at any convenient dock. Many of them assembled near the foot of Manhattan Island where they were loaded or unloaded usually by hand power in a primitive manner. To-day the canal craft use a special terminal in the Gowanus Bay, constructed at a cost of $6,000,000, which is doubtless the largest and busiest canal boat harbor in the world. Here the canal barges are brought alongside modern steel piers or directly to ocean-going craft for transhipping their cargoes. Every labor-saving device known in modern harbor equipment is provided to facilitate the work. The heavy articles of the cargo are raised and lowered by electric cranes directly from the holds of the canal craft. The leisurely canal boatman of yesterday finds himself in a new world.

Within the memory of the old canal boat captains New York harbor has undergone a surprising transformation. Fifty years or more ago his craft played a highly important part in the activities of the port. The raw materials then carried, a few tons at a time, by canal boats from the Great Lakes fed countless industries. To-day fleets of steel canal barges each carrying 2,500 tons of ore make the same trip at much increased speed.

Another generation may trace the transformation of the harbor to the appearance of these new fleets.

Many of the modern canal craft are equipped for carrying cargoes of steel. The dock equipment for handling heavy cargoes greatly facilitates the new traffic. New York and other cities reached by these fleets consume steel in immense quantities. It is predicted that this cheap transportation of steel products will result in the building up of new manufacturing centers, since the crude material can be brought by water to some port on the Great Lakes, such as Buffalo, to be manufactured into finished products for ultimate shipment to New York.

In building the Panama Canal the United States performed a service which will profit the commercial interests of the world for centuries to come. It is one of the outstanding engineering feats of all history, and, in the stimulus it has given to world commerce, it has fully justified the high hopes of its builders. The project of cutting a canal through the isthmus was first discussed nearly four centuries ago. When it was discovered early in the sixteenth century that this comparatively narrow strip of land blocked the route to the East, the engineers of the day at once began to plan, however crudely, an artificial waterway to join the two oceans.

As early as 1550 a book was published urging that work should be commenced on the waterway without delay. The route from Panama to Porto Bello was favored at this time, and feeling ran so high that it was urged that any one favoring any other route should be punished with death. For fully two centuries, however, no steps were taken looking to its actual construction. In 1771 the Spanish Government ordered a survey to be made of the isthmus. The first dependable survey of the route of the proposed canal was not made until 1869, and was carried out by engineers of the United States. Following this report interest in the proposed waterway became general. Elaborate preparations were made by the French, and considerable work was done. The preliminary engineering surveys were skilfully made, but the task failed because of the extravagance and corruption of those entrusted with the work.

The problem at Panama was highly complicated. In digging the Suez Canal it had only been necessary to cut a channel through level sand and flood it with water. At Panama the continental divide which must be cut away was 335 feet above sea level. An enormous amount of excavation must be done and precautions taken to keep the surrounding hills from slipping into the canal. Another baffling problem was to control the Chagres River, a torrential stream, which at times flooded the surrounding country. One of the greatest achievements of the American engineers was to make the pestilential tropical regions healthful and livable. In building the Suez Canal many thousands of lives were sacrificed, while at Panama the death rate was kept amazingly low.

The Panama Canal has a length of 43.8 miles between the deep water of the Atlantic

Ocean and the deep water of the Pacific. The minimum depth of the channel is forty-one feet, and in some sea tides it is increased. The lock chambers, designed to accommodate the largest steamers afloat, have a clear width of 110 feet and a length of 1,000 feet. The cost of building the canal was over $300,000,000, not including sums paid to the old canal company and indemnities paid to Panama.

The steady increase in ship tonnage passing through the canal especially since the World War is surprising. During 1923 20,000,000 tons of cargo passed through the canal, which was an increase of about 180 per cent. over that of the previous year. The tolls collected in 1923 were fully fifty per cent. more than in any preceding year. More than 4,000 commercial vessels carrying the flags of many nations passed through the great waterway in this one year. It is interesting to note that two fifths of all the tonnage passing through the canal moved between the Atlantic and Pacific ports of the United States.

CHAPTER XII

THE SCIENCE OF CANAL BUILDING

EVERY one has probably experimented in building miniature dams and channels in shallow streams or ponds. The study of hydraulics as applied to canal building, even in this elemental way, has a peculiar fascination. The canal holds a place in the imagination quite apart from the railroad or highway. This phase of the science of hydraulics is very ancient, and was highly developed even in primitive civilizations.

The canal builder faces a much more complicated problem in many ways than the engineer who lays out railroads or highways. Water, of course, inevitably runs down hill, and a canal must maintain a uniform level if it is to hold water. A railroad or highway may compromise with the general rise and fall of the country; not so a canal. A slight grade which would scarcely be appreciable on a railway would be fatal to an artificial waterway.

The canal must be built in a series of level reaches at various heights above a determined line. The engineer may of course employ curves in solving his problem and here is an opportunity for many ingenious makeshifts in cutting the contours. The larger the canal, however, the more gradual must be these turns. Study the course of a canal through some rough and intricate country, if possible from an elevation, and you will be amazed at the ingenuity displayed.

To maintain a dead level the builder of canals may of course dig deep into the hills or elevations, or he may build up the walls of his waterway above the surrounding country. Either method of construction is expensive, and is employed only as a last resort. One of the most difficult problems is to carry the canal across a sudden depression. In some instances canals have been literally raised upon stilts to bridge deep valleys. The water may be carried in an iron trough supported by steel or stone arches. It is a curious sight to watch strings of canal boats thus sweeping across the sky line. In some instances it is necessary to actually tunnel through hills or mountains, so that the canal craft finds itself at times gliding forward in sudden darkness.

The canal must be so planned that the resistance offered to the boat by the water will be the same as in an open stream of a natural body of water. A complicated mathematical problem must thus be solved. The standard width of a small canal is twenty-five to thirty feet at the bottom and from forty to fifty feet at the water level, with a depth of four or five feet. The angle of the sides of the canal is adapted to the nature of the soil. The details of such construction was worked out centuries ago.

It is not enough merely to dig a waterway and flood it with water. The nature of the soil must be studied with anxious attention. If the earth be porous, the water will escape, especially on embankments, and the sides must be lined with puddled clay throughout. In digging the canal this lining must of course be allowed for, since it may be two or three feet in thickness. If the canal is traversed by numerous craft the wash from the boats may wear away the sides and a special lining of stone must be provided. With the appearance of steam tug boats and motor-driven craft on canals the effect of waves, or the wash set up within the canal, must be guarded against. In some of the old canals the sides have been cut away and a perpendicular wall built along both sides. This serves to widen the canal and guard against the disintegrating effects of the water.

It is much more difficult to keep a canal brimming full of water than the layman in such matters imagines. The water supply must be sufficient to last through the driest seasons of the year or the canal will be effectively closed to all traffic. Every possibility of a drought must be anticipated. There is a constant loss of water on so large a surface from evaporation, varying with the temperature. A long hot spell of weather might so lower the level of the canal that its traffic would be stranded. In some cases where the water supply cannot be maintained smaller boats are used during the summer months. There is also a great loss of water by seepage through the sides of the canal. In some soils this loss is much more serious than in others, and the engineer who plans the canal must not make mistakes.

The water supply depends as a rule upon lakes and streams at convenient points along the route. In some cases it is necessary to build artificial reservoirs to assure an adequate supply. It is scarcely less vital for canals to have a continuous water supply than it is for a city, although of course the quality of the water is not essential. The source of supply, whether from lake, stream or reservoir, must be kept at such an elevation that it will flow to the summit level of the canal or be pumped to a sufficient height.

Too much water is almost as serious a menace as a drought. If the water rises above the banks and overflows in any quantity the tow path will be damaged and perhaps destroyed. It may be a very serious matter, again, for water in considerable volume to overflow the adjoining land. A sudden downpour of rain may flow from higher ground into a canal, increasing its volume dangerously, and the pressure may break the confining banks and inundate towns or cultivated lands, doing immense damage. To guard against such dangers, waste weirs are constructed to discharge the water accumulated in floods. Stop gates are introduced at intervals of a few miles, which in times of flood may be opened or shut and the water controlled. Mark Twain's famous poem, "The Raging Canal," actually has some basis on facts.

The canal lock, at once so primitive and efficient a contrivance, has been employed for centuries with little change. Whether built of wood or complicated steel structure the principle remains exactly the same. The boat is locked in a basin of water, the gates to the lock or basin of another level are opened and the waters of the two locks equalized, when the craft floats gently up or down to the new level. It is one of the most fascinating demonstrations in the science of hydraulics.

Modern engineering has marvelously developed the details of the canal lock without in the least improving upon the system. The clumsy wooden lock gates of the old canals served to lift or lower a small boat a few feet, while a single mule provided the motive power. In the great locks at Panama the largest steamers and battleships are lifted and lowered like toys while the powerful "electric mules" draw them through the channels, but the principle remains unchanged.

The amazing modern development of the canal is strikingly illustrated by comparing the early makeshifts for raising or lowering canal boats from one level to another with the efficient machinery employed to-day. The expense of constructing locks was sometimes avoided by building an incline or ramp between the two levels and laboriously hauling the canal boat up this incline. Several of these inclines may still be seen, long fallen into disuse, upon the older canals.

The photograph reproduced on page facing page 273 illustrates the system employed. Only small boats could be hauled up these inclines. The craft left the water upon which it had been afloat, and made the journey to the new level, overland, with its entire underbody exposed. There have been instances of canal boats being wrecked beyond repair by accidents during these land journeys.

One gains a new impression of the importance of the great canals of the world by comparing the amazing cost of their construction. Obviously these great sums would not have been expended if the investment had not been warranted. The cost of the most difficult railroad construction becomes insignificant by comparison. The following table gives the average cost per mile for constructing the great canal enterprises of the world.

Chicago Drainage Canal	cost	per	mile	$1,110,000
Kiel Canal	"	"	"	735,000
Suez Canal	"	"	"	500,000
Manchester Ship Canal	"	"	"	2,100,000
Panama Canal	"	"	"	9,000,000

The levee is one of the most ancient of engineering enterprises. The problem of controlling rivers which overflow their banks and carry destruction to the lands which border them is very old. It is probable that primitive men fought this menace in the dawn of history, and the building of levees had been reduced to a definite science by the time history came to be recorded. Traces of ancient levees, long fallen into disuse, were discovered by the Romans and were attributed by Pliny to the Etruscans. The early Egyptians learned to stem the flow of the Nile centuries before the Christian era.

The Romans developed an extensive system of levee building for controlling floods. The levees built by them along the river Po proved very effective and remained continuously in use for centuries. In many countries, notably Holland, the existence of great areas of land depends upon the barriers set up against the floods. The destruction wrought by the breaking of levees, measured both in loss of property and human life, has been enormous.

In their simpler forms a levee is merely a line of embankment forming artificial banks for a stream. The systems of levees adopted in foreign countries have been repeatedly studied by American engineers and adapted to domestic use. The levees of the Mississippi River are by far the most extensive in the world. In no other country is so difficult a problem of flood protection encountered. These artificial embankments confine the river below the mouth of the Ohio for a thousand miles. An immense area of some 30,000 square miles is here subject to overflow and must be protected at all costs.

The levees of the Mississippi date back two centuries. A series of detached levees were first constructed, which later were extended and strengthened. The flood surface varies from five to ten miles in width. In this general region more than 2,500 miles of levees have been built at a cost of about $30,000,000.

By far the greatest project of river development ever undertaken, in America at least, is the deepening of the channel of the

Mississippi River. The Government has been "disciplining" the river for more than half a century. The work of controlling the intractable waters of the Mississippi, although simple in theory, has been found to be extremely baffling. Its waters have a curious habit of spreading at times over the wide bed of the river and deserting the channel available for boats. Many factors must be considered in calculating the flow. The spring freshets often play curious tricks with the river in shifting the channels, while a dry season may completely close navigation. Millions of dollars have been expended in dredging channels which have disappeared almost overnight.

Long before the Civil War, Robert E. Lee was directed by the War Department to plan various improvements. An attempt was made in 1878 to establish a minimum channel four and a half feet in depth. At that time it was possible for freighters of light draft to navigate the Mississippi as far north as the Twin Cities in ordinary seasons, but the channels were not dependable. A new plan of controlling the waters and assuring a channel in all seasons was inaugurated in 1907. Some $15,000,000 have been spent to date in this work, which is now more than half completed. The goal of a continuous channel throughout this long reach of the "Father of Waters" is at last in sight. During the spring of 1924 a barge carrying a cargo of freight taken on at St. Louis and other points down the river succeeded in reaching the Twin Cities.

The latest attempt to control the wanderings of this long and tortuous channel consists in building a great number of wing dams on both sides of the stream throughout its course. These are odd looking structures built of brush or stone, jutting out into the river. They vary in length from a few yards to hundreds of feet. Some 3,000 of these dams have already been built between Minneapolis and Prairie du Chien, Wis., and about 1,000 more are still to be added. They serve to narrow the channel, and it is believed will ultimately maintain a depth of six feet at low water throughout the upper section of the river. It is planned to provide a channel ranging in width from 300 feet at the upper end of the course to 1,400 feet at the mouth of the Missouri.

New barges have been especially designed for service on the upper Mississippi, which will operate in less than six feet of water. Adequate terminal facilities are also planned. A transfer unit has already been built at Alton, Ill., with railroad connections and machinery for transhipping freight, to provide efficient facilities for the river trade which is expected to develop, and sea-walls have been built and railroad tracks installed in convenient positions at St. Paul, Minneapolis, Davenport and Muscatine. All proposed terminals will be municipally owned and will be available for public use. The maintenance of a dependable channel between the Twin Cities and St. Louis will provide an important outlet for the products of an immensely rich region to the lower Mississippi below St. Louis. Ultimately Lake

Superior may be connected by a waterway, 2,000 miles long, reaching to the Gulf of Mexico.

More than thirty rivers throughout the United States have been canalized over a total length of 4,385 miles. The work was commenced in 1840. The depth of these waterways vary from channels of two feet to fourteen feet, and in some cases they extend for several hundred miles. The total outlay for this work has been over $100,000,000.

A LIST OF THE CANALIZED RIVERS OF THE UNITED STATES:

Name	*Opened*	*Total Length*	*Cost of Construction and Improvem't*
New York			
Hudson River	1915	38.00	$3,807,833
Pennsylvania			
Monongahela	1879	128.00	8,105,050
Ohio	1885	968.50	39,603,695
Alleghany	1902	24.00	1,454,424
West Va.			
Great Kanawha	1889	90.00	4,248,042
Little Kanawha	1874	48.00	259,082
North Carolina			
Cape Fear River	1916	32.00	824,462
South Carolina			
Congaree	1904	2.00	281,000

Name	*Opened*	*Total Length*	*Cost of Construction and Improvem't*
Ohio			
Muskingum	1840	91.00	2,360,690
Illinois			
Illinois	1889	223.00	2,903,757
Wabash	1893	12.00	260,000
Galena	1894	6.00	100,000
Wisconsin			
Fox	1856	176.00	3,894,159
Minnesota			
Mississippi River	1907 1887 1907	19.36	8,354,430
Missouri			
Osage River	1906	7.00	635,809
Kentucky			
Kentucky	1844	255.00	4,094,442
Green & Barren	1841	225.50	2,774,365
Big Sandy & Tug & Levisa Forks	1897	39.00	1,568,659
Rough	1896	29.50	106,500
Tenn. & Ky.			
Cumberland	1905	326.10	3,221,836
Cumberland	1905	192.60	2,092,173
Alabama			
Black War'r. Tombigbee	1895	362.50	$9,652,881
Coosa	1890	165.50	2,357,517

Name	*Opened*	*Total Length*	*Cost of Construction and Improvem't*
Arkansas			
Upper White	1904	33.00	813,197
Ouachita	1912	119.00	1,819,511
Texas			
Trinity River	1909	330.50	1,923,038
Brazos River	1915	424.00	1,326,933
Oregon			
Yamhill	1900	18.00	72,165

CHAPTER XIII

PROPOSED AMERICAN WATERWAYS

THE United States may have eventually an extended system of canals and canalized rivers, far surpassing that of Europe or any system which Europe may develop. The geographical form of our country lends itself admirably to this purpose. The United States is a solid continent, so to speak, while Europe is a great peninsula or rather a series of peninsulas. Much of Europe lies near the sea, and there are few large areas which cannot be reached from the sea with comparatively little overland travel. The city of Moscow, for instance, is only as far inland as is Cincinnati. There are few countries in Europe without a sea coast or convenient access to the sea.

The United States has an immense territory lying inland which is hopelessly cut off from the great ocean highways. The contrast between the two continents can be readily visualized by placing the maps side by side, or better by superimposing the map of Europe over that of the United States. There is compensation for America, however, in the prodigality with which Nature has supplied the country with great rivers. The United States has 28,000 miles of nominally navigable waterways. The total length of river channels in Europe appears unimportant by comparison.

This enormous mileage of river channels may become the basis of a system of canalized streams which will revolutionize the freight traffic movement of the entire country. There are to-day 14,000 miles of navigable river highways in the United States with a minimum depth of three feet. These channels may be deepened for the most part by simple dredging, which is the cheapest form of canal building. Thousands of miles of such channels may be developed with but slight expense for building locks or similar engineering problems, common to canal construction.

With the map of the United States before one a number of possible canals suggest themselves. It is obvious of course that the Great Lakes should be connected by serviceable channels with the Atlantic. The Mississippi River, with its tributaries, extends so far northward that deep artificial connections with the Great Lakes appears to be a comparatively simple matter. The rivers of the southern States emptying into the Atlantic have their source in the same mountain ranges from which other streams rise to flow westward to the Mississippi. Could the intervening country be traversed by canals a more or less direct route would be established between the great valley of the Mississippi and the Atlantic seaboard.

The inland waters of the eastern regions of the United States are admirably adapted to the construction of a great system of canals. The opportunity offered for similar construction in Europe is far less favorable. In the countries which have been most highly canalized, notably Holland and France, distances are of course very much less than in America.

A century or more ago Europe realized the possibilities of canals and planned and constructed artificial waterways on an unprecedented scale. America has so far been sufficiently well served by her great natural waterways, with comparatively little assistance from artificial channels, and as the railroad mileage of the United States is so much greater than that of Europe the need of artificial waterways has not been pressing.

Countless canal enterprises have been conceived throughout the country. Should all these plans be realized the United States will some day be gridironed with artificial waterways. The inhabitant of neighboring planets may some day gaze upon the North American continent and marvel at a system of canals rivaling the reputed waterways of Mars.

The greatest canal problem before the country to-day is doubtless the so-called St. Lawrence Ship Canal. In some ways the project is more important even than our achievement at Panama. It will make possible direct navigation of sea-going craft between the Atlantic Ocean and the Great Lakes. Many cities which gather the immense resources of the West and Northwest, both of the United States and Canada, will thus be put in direct communication with foreign ports. The influence of such a waterway upon the development of vast areas of North America and upon the oversea trade routes of the world can scarcely be estimated.

In 1920 the Governments of the United States and Canada referred to an International Joint Committee the work of investigating what additional improvements were necessary along this route and a report was made in 1922. It has been urged in the United States Senate that the United States should pay for the construction of this waterway, so obvious would be its advantages in affording free passage for ocean-going vessels from the Great Lakes to the sea. Incidentally the water power now going to waste, which would become available on building the canal, would total over 4,000,000 horse power and it is estimated would assure an annual income of $15,000,000.

An interesting international problem is presented in the building of the canal. The St. Lawrence River is of course an international boundary line. Were this situation to arise in Europe the rivalry and mistrust of the countries bordering such a river would seriously complicate the problem. In America, happily, there is no such difficulty. When this phase of the problem was discussed in the Canadian Parliament it was agreed that the possibility of war between the United States and Canada was so remote that it might be disregarded. It has been urged that the canal might fittingly be built at this time to celebrate the anniversary of one hundred years of peace between the two countries. Treaties now exist between the United States and Canada providing that the navigation of all boundary waters shall be forever free to both nations for purposes of commerce. These rights extend to Lake Michigan and to all canals connecting the boundary waters now existing or which shall exist in the future, on either side of the line—a sufficiently broad agreement.

It is generally agreed that such a canal would become one of the great artificial waterways of the world, bringing to a new focus many of the great sea routes. Just what will happen when fleets pass back and forth over this route is a subject of lively discussion on either side of the international boundary. Existing means of transportation from the Great Lakes to the sea are obviously inadequate so far as the United States is concerned. The canal will make possible, it is claimed, a substantial reduction of freight rates to and from Europe. It is estimated that the expense of freight for the lake ports for grain and other classes of products will be reduced from one half to two thirds.

The potential energy of the western regions of the United States and Canada is almost limitless. With such a stimulus it is agreed that an enormous acreage will become available for growing grain, and the natural wealth of regions as yet only partially developed will be brought in closer touch with world markets. Every section of the great inland areas of America will doubtless feel the stimulus. A few small vessels ply today directly between lake ports, notably Chicago, and foreign countries, which seems to indicate the route which the greater fleets will some day follow.

The new St. Lawrence Canal will have a bitter rival in the old Erie Canal or Barge Canal, which has long served as the principal outlet from the lakes to the sea. Each route has advantages of its own, and the struggle between them will be an interesting one. The Erie Canal, even as enlarged to accommodate barges, is not large enough for the passage of lake vessels. The barges, moreover, cannot safely navigate the Great Lakes, and it is necessary to tranship cargoes from the lake boats to the barges at Buffalo. Once these barges reach New York, it is necessary to again transfer their cargoes to ocean-going vessels for shipment to foreign ports. The time of passage from the Great

Lakes to the sea over the St. Lawrence or Erie route is about the same.

Another factor to be considered, however, is the long Canadian winter. The Erie Canal is open to navigation on an average of 204 days in the year. The rest of the 365 days is lost time. The St. Lawrence Canal would be frozen throughout even a longer period. Again Montreal harbor is frozen hard and fast for several months of the year. New York, on the other hand, is always open to navigation.

In the past railroads have carried the canal trade or much of it when lake and canal navigation was closed. It would appear therefore that when the St. Lawrence Canal is closed in winter New York will inevitably get this traffic over the railroads. The plan, however, of utilizing the railroads will work equally well in Canada. It is very likely that the Canadian Government may influence the railroads of the Dominion to carry wheat more cheaply than the railroads running into New York, in order to make Montreal put up the most important grain port. Throughout the summer there would be a great economy in bringing wheat directly from lake ports to Montreal and loading it directly upon ocean-going vessels in that harbor.

There are no insurmountable engineering difficulties to be encountered in constructing a great ship canal via the St. Lawrence valley from the Great Lakes to the sea. The St. Lawrence River rises in Lake Ontario and reaches by a direct route the Gulf of St. Lawrence. The level of Lake Ontario is 246 feet above the sea, and this fall makes it possible to develop an enormous water-power, while at the same time the inequalities of the channel will necessitate the building of many great locks. It is planned to construct a canal extending from Montreal to Lake Ontario with a depth of twenty-five feet, which later may be deepened to thirty feet. A continuous channel will be made possible by constructing a series of locks with short canal sections and by dredging channels in the natural waterways. It is estimated that the canal will cost $250,000,-

000 or more, and will require fifteen years to build.

The saving in distance between the lake ports and Europe by the building of the St. Lawrence Canal is considerable. From Duluth to Montreal, via the proposed Georgian Bay route, the distance is 997 miles. The distance from Duluth to New York City is 1,500 miles. Montreal lies 1,000 miles from the sea, but its latitude is more favorable than that of New York. The sea route from Montreal to Liverpool is 2,972 miles long and from New York to Liverpool 3,052 miles. The canal would effect a saving in the water trip from Duluth to Liverpool of more than 500 miles. A channel twenty-two feet deep through the canal would permit the passage of the large lake vessels from inland ports to the sea.

There are at present several projects for building a ship canal from tide water to the Great Lakes. One contemplates improving the present waterway, passing through Georgian Bay, Lake Nipissing and the Ottawa River. Another plan is to pass through the Great Lakes via the Welland Canal. Still another enterprise is to enlarge the present St. Lawrence Canal system by building a great system of locks and dams and improving the river channel. It has been argued in Canada that the Georgian Bay route, in the event of war, would have the advantage of being wholly in Canadian territory. Neither of these proposed canals, it is believed, would suffice to meet the demands of the trade in the near future.

In a few years we may enjoy the unusual sight of seeing ocean liners and great ships gliding through the fields and woods of New Jersey. A great ship canal, capable of accommodating vessels of 5,000 tons or more, has been planned to cross that State, from New York harbor to the Delaware River, thus allowing ocean-going craft to ply quickly and safely between New York and Philadelphia. It would be a sea-level canal throughout, without locks, so that steamships could navigate it.

The surveys completed by the War Department show that there are few natural obstacles in the path of such a canal. It would roughly parallel the present Delaware and Raritan Canal, but cross the State by a more direct route, shortening the distance to the Delaware River by approximately forty-three miles. The canal will follow a natural valley and by widening and deepening the present canal would require comparatively little new excavation. The entrance to the ship canal from New York harbor will be west of Staten Island, inside the Narrows, so that vessels could make the trip from New York to Philadelphia without going to sea. The present sea trip between the two cities is 274 miles in length, while the distance by the proposed ship canal will be only eighty-seven miles, which is less than the railroad mileage between the two cities.

It is planned to make the ship canal twenty feet deep throughout and 125 feet in width. The ocean freight liners could thus readily navigate the channel, and pass one another with perfect safety at a comparatively high speed. The water journey between the two great cities could be made in a few hours.

It is estimated that the canal would, from the first, carry 52,000,000 tons of cargo a year, and that this enormous tonnage would grow in years to come. On such a canal box barges could be employed which would make it possible to carry freight for about one half the cost of ocean-going barges. This link between the two great cities of New York and Philadelphia would quickly increase the volume of present traffic between them. An inland waterway of such dimensions would also be invaluable in the event of war.

The entire seacoast of New Jersey, from Cape May at its southern extremity to Sandy Hook at the entrance to New York harbor, is pierced by many bays and inlets, often connected by inland channels which admirably lend themselves to canal building. For many miles a continuous inland waterway has been dug by Nature just behind a long fringe of beach. By digging the connecting links between the system of bays and rivers and canalizing the natural channels a unique canal system is being developed. The work has been in progress since 1908. The channel of the canal is six feet in depth and the width at the narrowest point one hundred feet. The New Jersey Inland Waterway, as it is called, will make it possible to link up cities and coast resorts for more than a hundred miles along the Atlantic shore—places which in the summer months attract an enormous population.

Eventually the Great Lakes will doubtless be connected with one another by several new artificial channels. A tempting short cut is proposed between Lake Michigan and Lake Erie. It is necessary at present to make a long detour via the Straits of Mackinaw. A canal has been projected from the southern end of Lake Michigan to Lake Erie, which will cost $100,000,000. An enormous volume of traffic would be deflected to this shorter route. Such a canal would make it possible for Chicago to ship almost in a straight line to the eastern lakes and thence by the St. Lawrence Canal to the Atlantic, while many cities, including Cleveland, Detroit, Buffalo, Toronto and Montreal, would benefit by the straightening and shortening of the traffic route.

Another proposed lake canal is the Grand Saginaw Valley Waterway, to connect Lakes Michigan and Huron. The plans utilize the Grand and Saginaw Rivers which traverse part of the route. There are few natural obstructions to be overcome, and the cost of construction, $20,000,000, is considered comparatively low. The long trip to the north end of Lake Michigan would be saved and the canal would tap a very rich country by traversing the most populous part of Michigan.

Still another outlet from the Great Lakes will be afforded by the Upper Mississippi River Improvement, as has been previously stated.

A ship canal has also been planned to connect the Great Lakes with the Atlantic by a route following that of the present Erie Barge Canal. Surveys have been made for a canal which has been estimated to cost $200,000,000. The enterprise has been abandoned, temporarily at least, since the building of the present Barge Canal from Lake Erie to the Hudson River.

One of the most obvious opportunities for canal building would seem to lie in the comparatively narrow region which separates the Ohio River from Lake Erie. The commerce of the Great Lakes could thus find an easy outlet to the long waterway which flows through the Mississippi Valley to the Gulf of Mexico. Such a canal has been definitely planned to accommodate freight-carrying ships of considerable tonnage. The channel is to be fourteen feet in depth. It will leave the Ohio River twenty-six miles from Pittsburg and utilizing the channel of the Beaver River enter Lake Erie at Indian Creek. The length will be one hundred and three miles; the cost of construction $53,000,000. The great industrial plants of Pittsburg could thus be fed with raw materials by an all-water route from the Great Lakes.

The Ohio River offers wonderful opportunities for development. It drains one of the richest valleys in the country, flowing past many busy cities. Beginning at Pittsburg it runs in a southwesterly direction for 968 miles to join the Mississippi River at Cairo, Ill. Originally the Ohio was obstructed by innumerable bars, and was only navigable during its higher stages. To render it navigable throughout its entire length some fifty-four locks were originally planned, although this plan has since been modified.

Several ambitious engineering enterprises for improving the river are contemplated. One of these is to canalize the river through its entire length, providing a channel of nine feet for nearly a thousand miles. The plan which was authorized by congress in 1911 means an expenditure of $63,000,000. Another enterprise is to build a dam of great height and strength to create a permanent harbor at Louisville. The water power thus obtained would develop 100,000 horsepower, which is now going to waste.

The shipping of the Ohio River has for generations played an important part in the development of this region and of the entire United States. This great channel made it possible to develop a wilderness into a densely populated region in little more than a generation. With the coming of the railroad much of this early commerce disappeared. The growth of Pittsburg at its headwaters into a great industrial center revived its importance. Many new towns and cities sprang up and to-day the river traffic is very heavy. The picturesque old river craft have given place to modern heavily laden barges. As reliable navigation is assured in its upper waters the Ohio will again become one of the great trade routes of the country.

One of the most obvious short cuts for coastal shipping along the Atlantic seaboard of the United States would be the elimination of the Florida peninsula. The great fleets which constantly ply between the Atlantic and Gulf ports must obviously make a long detour to round Cape Sable. To shorten this route a sea-level canal has been planned across Georgia and Florida. It would enter the Atlantic near Jacksonville and reach the Gulf of Mexico at St. George Sound. The distance overland is 256 miles, but by taking advantage of many natural channels only 159 miles of actual excavation would be necessary.

The channel as planned would accommodate the largest sea-going vessels. In the trip between New York and New Orleans the canal would save 597 miles of steaming, and would also bring New Orleans 412 miles nearer to Liverpool, and cut off a corresponding distance in reaching other European ports. The enormous traffic in cotton between New Orleans and England would thus be carried far more quickly and cheaply than at present. New Orleans, despite her distance from the sea of more than 100 miles, has attained the second position among the American seaports, and the proposed canal would lend her a tremendous advantage.

A large proportion of the population of the United States living in the Mississippi Valley look forward with confidence to the building of a great channel to accommodate sea-going vessels, connecting the Great Lakes with the Gulf of Mexico. Elaborate surveys of the entire route have been made. A commission has visited Europe to study canal problems of the Old World at first hand and profit by its experience.

The plans prepared provide for a continuous channel fourteen feet in depth from Lake Michigan to the Gulf. Ultimately it is planned to enlarge this channel to a great waterway twenty-four feet deep, capable of accommodating the larger sea-going vessels. The channel would pass through the Chicago Drainage Canal, the Illinois River and the Mississippi River. It is estimated that the cost of construction will be $152,000,000. Of this vast amount some $55,000,000 has already been expended on the work. The expense of building a twenty-four-foot channel has not been definitely estimated. It is over this route that Chicago and other cities of the Mississippi Valley intend to send sea-going vessels direct to Europe and Asiatic ports.

The Lakes to the Gulf Canal waterway has already given rise to a vigorous protest from Canada. It is feared by some Canadian engineers that the route would tend to drain Lake Michigan, and in turn other of the

Great Lakes, of an appreciable amount of water. It is argued that in time this would affect the level of the lakes and incidentally the ports on the Canadian side. If this theory be correct many lake ports would ultimately be cut off from the shipping which is their chief source of wealth. Even if the water was but slightly lowered, it is pointed out, the effect upon the present channels might be disastrous.

The harnessing of the Mississippi River has been one of the great engineering achievements of the world. The flow of water has repeatedly proved irresistible, sweeping before it at times every obstacle in its path. It was considered a great achievement to build jetties which would merely confine it within fixed boundaries. The great rapids at Des Moines, Iowa, were long recognized as an ideal position for utilizing its potential power, but the project daunted the shrewdest engineers. As early as 1837 Robert E. Lee directed attention to the immense wealth of power going to waste at this point, but it was not until 1910 that the attempt to harness it was made.

The river at this point is about one mile in width. The best engineering skill of the country was employed and an army of 2,000 workmen recruited for the work. The plans were made upon a gigantic scale. A cofferdam was built, twenty-four acres in extent. Within this enclosure was built a power house, a lock with gates actually larger than those of the Panama Canal, and a dry dock but one foot smaller than the largest in the country, that of the Brooklyn Navy Yard.

The great dam thrown across the river is built upon 119 spans forming a bridge 4,649 feet in length. To withstand the enormous pressure of the water, especially during floods, the dam was constructed with a great width at the base tapering gradually to the top. The foundations are sunk deep into the bed of the Mississippi and the dam rises to a height of fifty-three feet. The great wall successfully holds in check the flow of the river and for a distance of forty miles it has transformed the once dangerous rapids into a placid lake.

Each span of the long bridge is equipped with a spillway, raised thirty-two feet and tapped by a steel gate. The water thus harnessed, when set to work, developed 300,000 horsepower by the use of thirty 10,000 horsepower turbines. Some 60,000 horsepower of this supply is utilized in St. Louis.

CHAPTER XIV

BOSTON TO THE GULF CANAL

BY linking together the extended system of natural waterways paralleling the Atlantic coast and the Gulf of Mexico a continuous channel may some day be provided from Maine to the national boundary at the Rio Grande, more than 2,000 miles in length. The project is by far the most ambitious in the long history of canal building. Nature has gone a long way toward building this amazing channel, lending the engineers who will complete the work invaluable assistance. For hundreds of miles along the Atlantic seaboard and the Gulf this curious natural channel runs within sight of the sea, but wholly protected from it. Much of the canal has been built and an enormous wealth of commerce already flows steadily over it. No other country in the world enjoys the surprising natural advantage of a continuous coastal canal paralleling its seaboard.

The first section of this proposed channel, known as the Atlantic Intercoastal Waterway, will extend from Boston to Florida. A channel of twelve feet is to be provided without interruption as far as Beaufort Inlet, N. C. Southward from this point a channel of seven feet is contemplated. The Government surveys show that comparatively little of this route will require a new artificial channel. In some cases the existing canals need only be widened and deepened, and the rivers canalized to accommodate vessels of this draught. The entire route along the Atlantic seaboard has been carefully surveyed by the Government and a score or more of canal projects definitely planned to connect the present waterways, natural and artificial, along the route.

On reaching Florida the canal will cut across the peninsula to the Gulf of Mexico to connect with another long intercoastal channel, part natural and part artificial, extending ultimately to the Mexican border. The great cities of the Atlantic seaboard and the Gulf may thus be connected by an uninterrupted water route independent of the sea. Practically one half the population of the United States will be able to take advantage of such a channel. The great industrial interests along these two seaboards may be brought in direct communication. A cheap and efficient means will be afforded for transporting raw materials to the place of consumption, and for the distribution as well of manufactured products. Such a line of communication may be compared to a belt line in a great harbor which affords cheap and efficient communication between the docks, with their shipping, the warehouses, the industrial plants and the railroad terminals, uniting them in a general unit. No other country has such an opportunity for coördinating its great highways of commerce.

The first link in the great Boston to the Gulf Inland Waterway is the Cape Cod Ship Canal. Large ships in our coast traffic can now readily pass through this channel, cut for a distance of eight miles through the sands of Cape Cod. This section of the route is not, strictly speaking, an inland waterway, but it enables shipping to keep close inshore and avoid the dangers of the outside passage. The canal was completed at a cost of $12,000,000.

Let us imagine the captain of some freighter or a passenger steamer of 5,000 tons leaving Boston bound for New York via this route. Instead of putting out to sea and rounding Cape Cod he may sail in more or less protected water via the Cape ship canal and reach Long Island Sound with little exposure and by a direct route. The canal boats starting from Boston bound for the south in the future may take advantage of the proposed Rhode Island Canal, thirty-one miles in length, planned to connect Narragansett Bay with Long Island Sound. The passage will be simplified by the fact that the greater part of this canal will be filled by tide water. The canal craft will thus reach the shelter of Long Island

Sound without facing possible storms from the sea.

Still another route may be opened for either the ocean liner or the canal fleet by cutting directly across the eastern section of Massachusetts. An inland route, known as the New York, Brockton and Boston Waterway, has been definitely planned across the State. It will provide a channel of twenty to twenty-five feet, thus enabling the largest ships in our coastal trade to make the passage. The canal will leave the Atlantic near Boston and passing through Brockton reach Narragansett Bay, which opens into Long Island Sound. An enormous volume of shipping passing between New England ports and New York would be diverted to this new channel. It is believed that the cost, estimated at $50,000,000, would be fully justified.

For a hundred miles Long Island now forms a natural barrier against the sea and in these sheltered waters of Long Island Sound the route leads to New York.

When New York is reached the canal fleet may enter the Delaware and Raritan Canal, directly from the upper harbor, without being exposed to the sea storms. The largest canal craft will have no trouble in navigating this waterway, for the channel is even now being enlarged at a cost of $15,000,000. Ultimately a ship may cross the northern section of New Jersey through the proposed twenty-five-foot-channel ship canal. A trip of thirty miles across country will then bring the boats to the Delaware River leading directly to Philadelphia. The cargo from Boston, or part of it, may be intended for the great manufacturing city of Trenton or some new center which will have grown up on this route. Meanwhile the boats from New England doubtless have passed many similar tows, bound from Philadelphia or New York to New England.

Should the canal boat from Boston be bound for a point still further south a broad, deep channel is available. From the Delaware River the old canal running to the Chesapeake Bay is being greatly enlarged and may some day accommodate regular coastal ships of 5,000 tons or more burden. By utilizing the present waterway an expenditure of $17,000,000 will work this transformation.

Further to the south Nature has provided all the elements necessary for developing this inland waterway for hundreds of miles with surprisingly little assistance. Glance at any map of the Atlantic coast below the entrance to Chesapeake Bay and the opportunities are obvious. Off Cape Hatteras, as all the world knows, lies the roughest and most treacherous seacoast of the continent. Against these storms nature has set up a natural barrier behind which lies a broad expanse of quiet waters. With comparatively little preparation an artifical waterway has been constructed reaching for more than two hundred miles from Norfolk to Beaufort, N. C. The channel, which is known as the Norfolk and Beaufort Inlet Waterway, is partially constructed. A ten-foot channel can be built for the entire distance at an outlay of $2,500,000. This may be enlarged to a ship canal at a cost of $35,000,000.

This canal will avoid the dangerous passing of Capes Hatteras and Lookout.

Still further south lie long stretches of coast line admirably suited for canal building. The coast in this region is indented by countless channels and protected by coast islands and peninsulas. The shore is low, level and sandy. Throughout the long reach extending from Beaufort Island, N. C., along the coast of South Carolina and Georgia to Jacksonville, Fla., a channel is available paralleling the coast. Plans have been made for a channel six feet deep for the entire distance. A continuous route will thus be made possible from Boston to Jacksonville, which at no point will be more than a few miles inland. Throughout most of the distance the canal craft would actually be within sight of the sea. The geographical formations which make such a waterway possible are unique and have no parallel anywhere else in the world.

The Florida peninsula, in turn, is almost crossed by natural waterways leading to the Gulf of Mexico. From Jacksonville the St.

John River extends far inland, providing an excellent channel. Boats of eight-foot draught can to-day navigate a distance of 170 miles up this waterway. Work has been in progress for years on a number of canals in this region.

The shores of the Gulf of Mexico are also favorable for the construction of a great inland waterway, roughly paralleling the coast. One such plan, known as the Interstate Inland Waterway, contemplates building a channel nine feet deep along the Gulf coast from the mouth of the Rio Grande to Donaldsonville, La. It will utilize numerous bays and lakes. Work is already in progress on parts of this canal. The entire cost of construction will be $4,000,000. A great part of the shore is now paralleled by inland waterways.

It is not anticipated that canal boats will load at Boston to deliver their cargo at the Rio Grande, or the other way about. On the completion of this great chain of artificial waterways it may be possible for ocean-going vessels, drawing up to twenty-five feet of water, to navigate the inland channels for a distance of upward of 2,000 miles, while regular canal craft would find a continuous channel more than 3,000 miles in length.

Here will be a great ship canal over which fleets of craft, large and small, may pass quickly without encountering tides or currents or the storms of the open sea. The canals often suffer in competition with railroads because they do not come directly to the door of the mills or factories to load or unload their freight. There are no canal sidings like the spurs running from railroads to factory yards. But on such a ship canal there will be ample space for great industrial plants built directly upon the water, making transhipment of cargoes possible direct from the canal craft. A great artery may thus be developed serving countless industrial plants.

From this great "belt line" will radiate in time innumerable canals and canalized rivers which will serve as feeders reaching far inland. The New York Barge Canal connecting with the Great Lakes at New York provides a continuous channel for 500 miles. The most elaborate plan for an inland canal is probably the so-called Atlantic and Great Western Waterway which would connect St. Louis and the Mississippi River with the Atlantic coast at Brunswick, Georgia. It has been designed to pass through the heart of the South, thus draining an area of inexhaustible riches. This canal would be 1,508 miles in length. By utilizing several rivers along the route, notably the Mississippi, Ohio, and Alabama Rivers, only 265 miles of this distance will have to be covered by canals and slack water navigation. A channel five feet in depth has been planned throughout the distance. The cost of construction would be $40,000,000. Considering the magnitude of the enterprise the expense is regarded as low.

Another feeder of the great coastal belt line is the Sabine Lake Ship Canal to connect Sabine Lake in eastern Texas with the Gulf of Mexico. Plans have been completed for a channel either ten or twenty-five feet in depth. Another interesting canal project in this region is the Black Warrior and Tombigbee River Improvement. It contemplates canalizing three rivers, to open navigation from the coal fields of Alabama to Mobile Bay.

In the event of war the canal system along our seaboard might justify the expense of its construction. The position of the canals already in operation along the Atlantic coast of the United States is admirably suited for defensive purposes. Nowhere else in the world is so long and exposed a coast line so well equipped for defense by inland waterways. The part this canal system could be depended upon to play in case of attack has been planned in great detail.

The canals of the Atlantic seaboard for a thousand miles would serve as a reserve force, should an attack be directed against any section of the coast. They would afford a margin of safety in planning any campaign of attack or defense. No matter what the nature of the attack directed against us, the canals would serve to save priceless time in organizing our defense.

It is not generally realized that our coast has been twice attacked by foreign enemies, and that the experience has proved valuable in planning a system of defense by means of our canals for the future. When in the War of 1812 the British raided Chesapeake Bay and burnt the city of Washington, the only means of bringing our forces from other points along the coast was by slow overland routes. A chain of canals along the coast in this region would have been a great element of strength, making it possible to keep the forces to the north and south of the British army in touch with one another. It would have been extremely difficult with such a system to break up the American line of communication. The canal from the Delaware River, for instance, could have been employed to pour into this region an adequate supply of provisions and munitions of war in a short time when every hour was priceless.

During the World War the country was suddenly alarmed by the report of German submarine activities off the coast of Massachusetts. Under ordinary conditions the shipping on this coast was defenseless against such attacks, and the presence of the submarines would have paralyzed this commerce. The Cape Cod Canal proved a valuable means of defense. The shipping was able to pass in perfect safety through the canal, well inland and safe from the enemy. The canal being designed for the passage of large vessels, there was no ship in this region which could not avail itself of this protection. The incident is especially significant since it afforded a practical illustration of the service of canals in the event of an attack by submarines, which is a possibility in the future, should our coast be menaced.

Still another illustration of the value of our coastal canals was afforded during the Civil War. The Chesapeake and Delaware, the Delaware and the Raritan Canals served at critical times to transport both troops and supplies quickly and efficiently. Should an attack be threatened at any point along the Atlantic seaboard our entire system of canals would be instantly turned over to the Govern-

Photo by Brown Bros.

THE LARGEST CANAL-BOAT TERMINAL IN THE WORLD (NEW YORK HARBOR)

Photo by Brown Bros.

AN ANCIENT SUBSTITUTE FOR THE CANAL LOCK

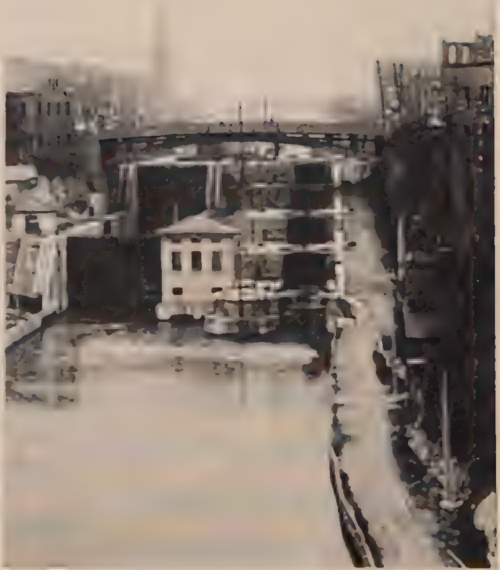


Photo by Brown Bros.

LOCKS ON THE NEW YORK BARGE CANAL

ment, and plans for utilizing them, prepared long in advance, would be carried out.

The problem, however remote, makes a fascinating study. With the present system of canals a complete inland waterway is available extending from New York to Norfolk. Throughout this distance the route would lie under the protection of fortifications and be absolutely impregnable from attacks from the sea. A continuous stream of traffic could thus pass without interruption across New Jersey, down the Delaware River and thence by canal to Chesapeake Bay.

It is pointed out by military experts that each of the harbors in this region would be an element of weakness. If Chesapeake Bay were occupied by the enemy it would serve as a valuable base for expeditions directed against Washington and Philadelphia. If Delaware Bay were taken and held it might serve as a base for attacks against Washington, Philadelphia or New York. Should an enemy gain and hold a position on Long Island Sound, New York would be seriously menaced.

The present system of inland canals serves to link together these three localities for mutual support. The strategic value of this system is of the greatest importance. Should any one of these harbors, Chesapeake Bay, Delaware Bay or New York, be successfully invaded, the armies of defense could swarm in through the canals. When our system of inland waterways is completed such an attack could be directed against any point along our coast from two or more directions.

The submarine promises to be an important weapon in the future, both in offensive and defensive attacks. Our system of inland waterways would make it possible to rush fleets of submarines from one point to another to be quickly assembled against an enemy attack, at any point on the entire Atlantic seaboard. The undersea craft, floating on the surface, could readily navigate the canals at a high rate of speed, safe from any possible attack which could be directed against them. A great fleet of these craft could be assembled along the canals for a thousand miles, awaiting an attack, and, once it developed, a fleet for defense could be mobilized in a few hours at any desired point.

It has been estimated by Admiral Benson that an enemy would be obliged to have four times our force to contend with a fleet so disposed, taking advantage of these canals. Suppose our coast was assailed by a great naval enemy force, we could thus quickly shift much of our navy to these natural waterways forming a great inner line of defense. Should an attack develop off New York, the Delaware or Chesapeake, a formidable fleet of these undersea craft and other lighter crafts capable of passing the canals could be mobilized at any of the great harbors of the region.

CHAPTER XV

SOME ECONOMIC ASPECTS

NO method of carrying freight overland has yet been devised which rivals in cheapness the deliberate but dependable canal boat. Despite the marvelous development of modern railroads the cost of transporting freight, distance for distance, cannot rival that of the waterways. Freight cars have been made larger, and more powerful locomotives have been built to draw trains of ever increasing length. The canal boat, meanwhile, has been enlarged and improved in design and the system of water transportation generally perfected. It is a question if the cost of railroad transportation of freight can ever be reduced to a figure which will compete with the rates of waterborne traffic.

We have previously stated that the average railroad freight rate in the United States during the past ten years has been about seven and one half mills per ton per mile, while on the Erie Canal the rate is about three mills per ton, per mile. The mileage rate varies on different canals, but it would seem to be a fair estimate that the freight rate on the average canal is about one half that of the railroads. These figures are taken from a report presented to the National River and Harbor Congress.

The cheapness of this means of transportation is graphically illustrated by calculating the distance one ton of freight can be carried for one dollar, by various vehicles. A horse and wagon can carry one ton of freight four miles for one dollar. A motor truck can carry it twenty miles at the same cost. On American railroads one dollar will carry a ton of freight 133 miles. In transporting freight through the "Soo" Canal one dollar may be said to carry one ton of freight 1,500 miles.

It has been found that a team of horses can haul 200 tons of freight on a canal boat with the same exertion required to move 100 tons on a railroad track or one ton on a dirt road. It would appear that the canal boat enjoys an unrivaled advantage over the steam or electric locomotive or the motor truck.

The influence of craft of various forms and sizes upon the cost of transportation has been worked out in great detail, both in Europe and America. The results are full of surprises. The depth of a channel in an inland waterway has been found to be of secondary importance in determining the freight transportation costs. On all waters where the winds offer little resistance the waves are naturally small. If the wind and waves are not considered, the power required to tow a vessel is doubled by doubling the draught of the vessel. Under the same condition the power required for towing is only increased from five to ten per cent. by doubling the length of the craft. It is obviously far cheaper to use a long boat of greater length than to increase the tonnage by doubling the draught of the boat. A shallow canal thus proves more economical than one of deep draught.

It has been found much cheaper, again, to use a large number of light draught boats combined in long tows, one behind another, or to use small boats with small power to each boat, than to carry the same load in a single vessel of deep draught. This is the European practice. It is extremely fortunate that vessels of light draught provide the cheapest form of transportation. It is obviously much cheaper to build shallow than deep canals.

A great transformation has come in designs of craft which navigate our inland waters. The old-fashioned canal boat, broad of beam with blunt prow and stern, remained little changed for centuries. Both in Europe and America no improvement could be found for this very clumsy craft until within the past few years. Suddenly, however, the lines of the prow were cut away, thus reducing the resistance and economizing the motive power. The boats were built with a broader beam, thus increasing their carrying capacity. The larger craft were built with a high box-like cabin which housed a greatly increased supply of freight. With such a design the "box barges," as they are called, can load and unload freight much more efficiently than could the old type of boat.

The latest forms of canal boats in American waters show an astonishing advance upon the older designs. They are skilfully designed to carry maximum loads with a minimum of resistance and power under conditions found in these artificial channels. The hulls are of steel and the prows are cut away like ocean craft. An enormous cargo space is provided, readily accessible through the wide hatches. The new forms of canal boats designed for the New York Barge Canal are especially efficient.

The patient mule could at best develop no higher speed than three and a half miles an hour, often much below this average for long hauls. A single tug now performs the labor of many mules with a gratifying increase in speed. The development of the gasoline engine has made it possible to introduce an auxiliary power which renders almost every form of canal craft independent of the tow-path.

It has been found that a gasoline barge drawing but two feet of water, moving through quiet waters, can carry the heaviest loads, in proportion to each dollar spent in cost of propulsion. A craft of this size can at present navigate without interruption 2,200 miles of the Mississippi River.

The canals of the country have gained in general usefulness and efficiency as they have become standardized. In the early days of railroads great inconveniences were experienced because of the difference in the gage of the tracks, while some rails were heavier than others. It was necessary to transfer loads from one car to another when a change in the gage of the road was encountered. The canals like the railroads need a common standard of width and depth. In inland navigation it is obviously more important that the draught should be the same for long distances than that a very deep draught be available for short distance. The efficiency of a canal system also depends largely upon providing efficient junction boat stations and large storage yards and anchorage basins at the mouth of busy tributaries. Profiting by the lesson of the past, special attention is being paid in America to-day to developing efficient canal boat terminals.

That the canal and improved river transportation has been one of the chief factors in developing the United States is of course obvious. Up to 1873 the canals of the country carried more freight, measured by tons, than the railroads. During the period ending in 1885 the canals carried fully one half the tonnage of the entire country. In 1858 steel rails were invented, and the railroads gained a great advantage. It is estimated that up to the year 1880 some ninety canals and waterways of the country carried as much freight as all the railroads.

The official Government figures of the tonnage of the country throughout this period are very significant. The total freight carried on all canals and canalized rivers, including that of the Great Lakes shipping, follows:

1880 — 21,044,292 tons
1889 — 48,668,325 "
1906 — 122,434,405 "
1916 — 225,938,929 "

In many parts of the United States the population in regions of improved rivers and canals has risen to 240 per square mile. In other words the population attracted by good waterways is more than twice as dense as the average through Europe, and almost equal to that of Germany. It is the general theory of waterways that they should be designed to connect areas yielding natural products with the markets for their consumption. Doubtless the most remarkable example of this rule of commerce is afforded by the Great Lakes.

There are many instances throughout the country where the railroads running parallel to the canals can underbid their rates. This condition is largely due to the lack of loading facilities on canals. A sea-going vessel carries its own cranes and derricks, or it loads and unloads at docks equipped with such machinery. Not so the canal boat. Its freight as a rule must be laboriously loaded or unloaded by hand, and this primitive method increases the cost of transportation. This handicap is in part overcome by equipping canal port terminals with labor-saving machinery. The canal boat which picks up and delivers freight at various points along the route, however, cannot enjoy such facilities. If a load of ploughs is to be delivered at some town along the canal, the boat must be detained while they are lifted from the hold by hand.

A railroad has sidings running from the main line directly into factories or industrial plants of various kinds. The canal cannot run branch canals into factories. The freight, however bulky it may be, must be unloaded to the dock, once again loaded upon railroad cars or motor trucks and hauled to its destination, and finally delivered. It sometimes happens that although the actual cost of transportation by canal is but a fraction of the cost of the railroad haul, the added expense of loading, unloading and carrying from terminal to consumer is greater than the cost of carrying it by rail, even without consideration of the time consumed.

The canals have enemies as well as friends. It is argued at great length by one group that the railroads in the long run can carry freight more economically than the canals and that the artificial waterways are doomed. Although it is admitted by these critics that the canals played a supremely important part in building up the country in the past, this was, it is pointed out, before railroads appeared, or at least had become efficient.

The friends of canal transportation contend that the future of canals is assured because they must always be the cheapest form of transportation for many of the heavier forms of non-perishable freight, and that the railroads can never successfully compete with the slow-moving but capacious canal boat. The canal freight problem, meanwhile, is receiving more attention to-day than ever before in the history of the country. Canal transportation, it is believed, will take on a new lease of life with the development of the canal terminal along scientific lines. These terminals will be equipped with the most up-to-date loading and unloading machinery. They will have transit sheds, traveling cranes and special machinery for handling coal, sand, bricks and other forms of heavy freight. The largest and best equipped canal terminal in the world has recently been completed in New York harbor at an expense of $6,000,000.

Throughout the greater part of Europe the canals have more than held their own against railroad competition. They form a great network of waterways, tapping the principal sources of inland supply and providing cheap and convenient transportation to the sea. In Holland ninety per cent. of all the freight traffic of the country is waterborne. Her canals have been constructed at enormous expense, and are kept in excellent condition. Although her area is but 12,741 square miles, Holland has at present 2,408 miles of canals in operation and 369 miles of fine navigable rivers. Several of her canals, notably the Amsterdam Canal, are remarkable engineering achievements and rank among the great ship canals of the world.

In Belgium inland navigation has been brought to a remarkable state of perfection. More than one hundred waterways are now in operation, with a total length of 1,345 miles, while more than $100,000,000 has been spent in improvements and maintenance. In a period of twenty years the traffic carried by the canals increased 120 per cent., while that handled by the railroads in the same period increased by sixty per cent. To-day this canal system carries more than 50,000,000 tons of freight a year. Considering the size of the country and its wealth this record is a convincing argument in favor of the canal.

Every one who has visited France will recall the picturesque canal boats which weave their way back and forth through every section of the country. France has more than 10,000 miles of waterways traversed regularly by this fleet, of which 3,000 miles are canals. The canal boats have an average capacity of 300 tons, and carry upwards of 50,000,000 tons of freight a year. In the last century France has expended about half a billion dollars on her artificial waterways, and the improvement of river channels, and is to-day, despite the losses of the war, planning to spend a similar sum in extending them.

Germany could not have carried on the World War without the assistance of her canals. Nearly all her rivers are connected by canals at strategic points, and all these artificial waterways are highly efficient. The Kiel Canal, providing a waterway between the Baltic and North Sea ports, proved indispensable during the war. A great network of waterways, totaling nearly 8,000 miles, makes it possible to carry every year more than 100,000,000 tons of freight. The mileage of the German canals has been little changed in fifty years, but the waterways have everywhere been enlarged and rendered more efficient. The rapid rise of Germany before the war is largely attributed to the cheap transportation within sea boundaries, made possible by her canals.

The British canals have long been an important factor in the country's transportation. At present there are nearly 5,000 miles of canals in operation in the United Kingdom. Their yearly traffic is nearly 50,000,000 tons. This record is remarkable in view of the fact that the English canal boats usually carry only from thirty to sixty tons of freight, and their progress is much delayed by the large number of locks. This total is again nearly one half the tonnage carried by the railroads. The British canals are almost all owned by private concerns and pay a substantial return on the investment, which is naturally large.

Previous to the World War one third of Russian freight was transported by water. The artificial waterways of the country have a total length of 1,225 miles, of which about one half are canals, the rest canalized rivers. The country has great natural waterways which well adapted to improvement. The total mileage of the rivers, lakes and canals is 239,161, of which one half is at present navigable. An ambitious plan has been discussed for many years of connecting the Black Sea with the Baltic by a canal 1,000 miles in length to cost about $100,000,000.

America is often reproached with having a system of canals distinctly inferior in many respects to those of Europe. As concerns the general efficiency of its artificial waterways the exact reverse is the case. This opinion has been expressed by European engineers, after a careful survey of the American canal situation. As one travels about Europe it is true that canals are much more in evidence. It must also be admitted that the European canals, as a rule, are in much better condition, and commendable care is taken in beautifying them. It must be considered, however, that Europe has been at work on her problem several centuries longer than America.

The United States, on the other hand, has more good navigable canals of ordinary draught than has France, Belgium and Germany combined. This includes artificial channels of two feet, six feet, ten feet and twenty feet. If all the waterways of Europe and the United States could be exchanged America would doubtless be the gainer by the transaction. The number and mileage of canals planned in America, which will be in large measure realized in the next few years, is much greater than those contemplated in all of Europe.

The geographical and commercial conditions of the United States are wholly different from those of Europe. Europe has a densely settled area. This means of course that Europe has more mouths to feed, more bodies to clothe and more products of every kind to be carried in proportion to its area than America. Throughout Europe there is an average population of 107 to the square mile, while in the United States the population is but forty-six per square mile. In Germany the density of population is 290 per square mile, and in Belgium 620.

When the United States, some centuries hence, becomes relatively as densely populated as Europe it will be extremely difficult to provide railroad and canal transportation sufficient to supply its people. Meanwhile, the building of canals promises to keep pace with the growth of population.

Canals of the United States

State and Name	*Opened Year*	*Total Length-Miles*	*Depth Feet*	*Cost of Construction and Improvem't*
Massachusetts				
Cape Cod Ship	1914	13.00	25	$13,500,000
New York				
Erie and Branches	1825	340.40	12	139,214,929
Champlain	1822	62.66	12	21,691,584
Oswego	1828	23.50	12	12,994,329
Cayuga & Seneca	1839	92.23	12	8,153,326
Black River	1849	35.00	4	3,894,952
New Jersey				
Delaware & Raritan	1834	44.00	8	5,113,749
Del. & Rar. (feeder)	1834	22.00	6	
Morris	1836	106.69	5	2,759,888
Pennsylvania				
Schuylkill Nav.	1825	89.96	6	11,055,557
Leh'h & Nav. Co.	1821	47.25	6	4,633,109
Del. Division Canal	1916	59.25	6	2,433,350
Delaware				
Chesapeake & Delaware	1829	29.63	10	5,000,000
Maryland				
Chesapeake & Ohio	1850	184.50	6	14,000,000

State and Name	*Opened Year*	*Total Length-Miles*	*Depth Feet*	*Cost of Construction and Improvem't*
Virginia				
Lake Drum (Dis. Sw.)	1794	23.00	9	3,301,000
North Carolina				
Fairfield	1868	4.00	7	60,000
Illinois				
Illinois & Michigan	1848	95.00	6	9,429,606
Chicago Drain & Ship	1900	38.60	22	55,208,889
Michigan				
Torch Lake	1875	4.00	20	597,075
Louisiana				
New Basin	1836	6.50	10	1,384,634
Old Basin	1794	5.50	5	227,352
Harvey's	1835	36.50	6	750,000
Company's	1836	97.00	6	600,000
Lake Borgne	1900	7.00	6	350,000
Government Canals				
New York				
Black Rock	1914	3.20	20	3,943,702
Delaware				
Lewes	1916	12.00	3	150,126
Virginia				
Albemarle & Ches'ke	1860	11.10	8	560,213
South Carolina				
Estherville—Minim Creek	1906	5.00	6	174,620

State and Name	*Opened Year*	*Total Length-Miles*	*Depth Feet*	*Cost of Construction and Improvem't*
Florida				
Channel	1915	36.50	5	505,930
Michigan				
St. Marys Falls—south	1855	1.60	25	9,046,349
St. Marys Falls—north	1914	1.60	25	5,041,291
Keweenaw	1873	25.00	20	1,786,379
St. Claire Flats	1889	3.33	20	1,288,891
Illinois				
Illinois & Mississippi	1907	75.00	7	7,555,999
Kentucky				
Louisville & Cortland	1830	2.00	9	6,960,920
Wisconsin				
Sturgeon Bay—L. Mich.	1881	1.36	21	559,637
Alabama				
Mus. Shoals & Elk R. Sh'ls	1890	18.00	5	3,191,726
Colbert Shoals	1911	8.06	7	2,322,179
Texas				
Port Arthur	1899	7.00	26	1,471,880
Galveston & Brazos	1853	36.00	4	233,654
Sabine Neches	1916	16.00	25	443,933
Oregon				
Willamette River	1873	0.66	2	841,186
Cascades	1896	0.57	8	3,913,198
Dalles-Celilo	1915	8.50	8	4,730,594

State and Name	*Opened Year*	*Total Length-Miles*	*Depth Feet*	*Cost of Construction and Improvem't*
Washington				
Port Townsend Oak Bay	1915	0.91	15	73,322
Lake Washington Ship	1916	8.00	30	3,442,865

RENEWALS 691-4574
DATE DUE

APR 10
FEB 14

Demco, Inc. 38-293

C00747938

HE
553
.C6

B1-884396

Library
University of Texas
at San Antonio

BRODART PRINTED IN U.S.A.